COLUMBIA BASIN PROJECT, GRAND COULEE DAM
AND FRANKLIN D. ROOSEVELT LAKE
(Grand Coulee Dam)
Across Columbia River 1/4 miles southeast
of the town of Grand Coulee
Grand Coulee
Grant County
Washington

HAER No. WA-139-A

HAER
WASH
13-GRACO
1A-

BLACK & WHITE PHOTOGRAPHY

WRITTEN HISTORICAL & DESCRIPTIVE DATA

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
U.S. Department of the Interior
National Park Service
Cultural Resources
1849 C Street, N.W., Room NC 300
Washington, D.C. 20240

HAER
WASH
13-GRACO
1A-

HISTORIC AMERICAN ENGINEERING RECORD

COLUMBIA BASIN PROJECT, GRAND COULEE DAM & FRANKLIN D. ROOSEVELT LAKE (Grand Coulee Dam)

HAER No. ~~AL~~ WA-139-A

Location:	Coulee Dam, Lincoln, Ferry and Douglas counties, Washington
Date of Construction:	1933-1941
Fabricator:	Mason-Walsh-Atkinson-Kier, Co. (MWAK); Consolidated Builders, Inc.; Western Pipe & Steel; Pelton Water Wheel Co.; Westinghouse Electric & Mfg. Co.
Present Owner:	United States Department of Interior, Bureau of Reclamation
Present Use:	Water storage, hydroelectric development
Significance:	At the time of construction, Grand Coulee Dam was the most massive structure ever built: construction-plant innovations realized during removal of an unprecedented volume of overburden and placement of an unprecedented volume of concrete established the dam "among the construction classics" and redefined the engineering and construction community's understanding of what was possible, within a given time frame and a given budget. Construction of the largest thing on earth allowed employment of over 70,000 men and created a stream of manufacture goods, dollars, and jobs that reached 45 states. This immediate employment places Grand Coulee with the major public-works projects of the depression era, representative of a significant new public/private social and economic contract. The unprecedented volume of water stored behind Grand Coulee Dam allows irrigation and cultivation of over half-a-million acres of land, a substantial impact on the economic and social history of the region. By March, 1944, this water volume, run through generators of unprecedented size, established a world's record for electrical production by a single plant in a month's time with a gross output of more than 621,000 kilowatt hours; this output powered Pacific Northwest aluminum plants and other World War II industries.
Historian:	Ann Hubber, Historical Research Associates, Inc., September 1997

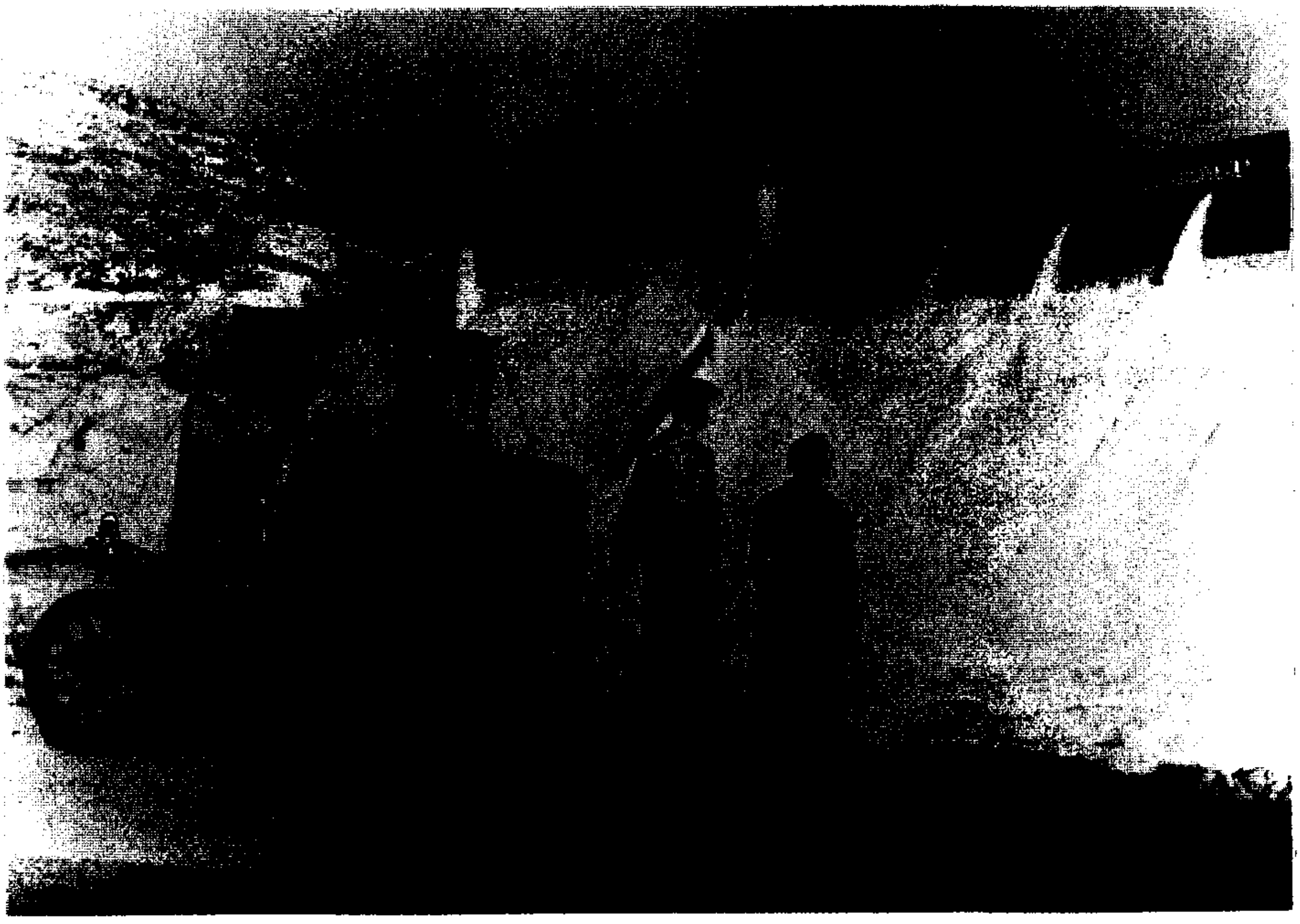
Project Information: This recording project is part of the Historic American Engineering Record (HAER), a program documenting historically significant engineering and industrial sites in the United States. The HAER program is part of the Historic American Buildings Survey/Historic American Engineering Record (HABS/HAER), a division of the National Park Service. The project was co-sponsored by the Bureau of Reclamation, Lynne MacDonald, Regional Archeologist; the Columbia Cascades SSO of the National Park Service, Stephanie Toothman, Chief, Cultural Resources; and HABS/HAER, Blaine Cliver, Chief. Ann Hubber of Historical Research Associates, Inc. wrote the historical report, and Jet Lowe of the HAER staff completed the large-format photography.

Section I
Grand Coulee Dam Construction History 1933-1942

Section II
Historic Photographs and Illustrations

All historic photographs are from the Bureau of Reclamation, Columbia Basin Project, Technical Data Center, Coulee Dam, Washington.

Section I
Grand Coulee Dam Construction History 1933–1942



Grand Coulee Dam, July 28, 1946. [Image #A1311.]

INTRODUCTION

On April 26, 1933, Commissioner of the Bureau of Reclamation Elwood Mead advised President Franklin D. Roosevelt that a low dam for development of commercial power could be constructed at the Grand Coulee of the Columbia as a first-stage unit of the Columbia Basin Project. As regional power markets waxed and the nationwide glut of agricultural land waned, this dam would be followed by a superimposed high dam and appurtenant irrigation system. Three months later, on July 27, 1933, construction of a dam at Grand Coulee was formally defined as a federal Public Works Administration (PWA) project, under the authority of Section 202 of the National Industrial Recovery Act. And, finally, on December 15, 1933, 50 indigent local men hired under the auspices of the National Reemployment Service began removing the first of 23,000,000 cubic yards to be excavated from the dam site.[1] Newly appointed construction engineer Frank A. Banks, Bureau of Reclamation, described the project's multiple facets and most immediate purpose:

> In times such as these, a project of this character serves to start the wheels of industry, to provide employment for those who are idle in all parts of the country and, as economic conditions become normal, power at reasonable rates will be available for new and expanding industries and homes, with a means of sustenance available for some of those who for the past few years have been dependent upon relief for mere existence.[2]

Mead's April recommendation and the ensuing federal funding and control of the massive Columbia Basin Project followed over forty years of "analytical studies, debates and animated controversy" over the feasibility of reclaiming the Columbia Plateau's arid Big Bend country with water of the Pend Oreille or Columbia rivers.[3]

The Columbia River heads in the mountains of British Columbia, Canada, enters the United States at Boundary, Washington, and meets the Pacific Ocean at Astoria, Oregon on the Washington/Oregon border. In its 400-mile run through Washington, the river drops over 1,000 feet, a rapid descent strengthened by an extreme floodwater volume of almost 500,000 cubic-feet-

[1] "Can the Columbia Be Controlled?", *Earth Mover*, June 1937, n.p.; USDI, BOR, "Annual Project History, Columbia Basin Project," Vol. I, 1933, Columbia Basin Project, Project Histories, Record Group 115, National Archives and Records Administration, Rocky Mountain Region, Denver, Colorado [NARA-RMR], p. 9.

[2] F. A. Banks, "Columbia Basin Project is Described by Construction Engineer," *Southwest Builder and Contractor*, November 23, 1934, p. 9.

[3] "Power, Navigation and Irrigation in Two Projects on the Columbia," *Engineering News-Record*, November 29, 1934, p. 680.

per-second (cfs) downstream of the Spokane River and 1,000,000 cfs downstream of the Snake.[4] And yet much of the country through which this water flows is arid, screened from western Washington rains by the Cascade Mountains rain shadow and seemingly blocked from affordable and technologically feasible irrigation by the precipitous canyon that the Columbia cuts around the "Big Bend" country of east-central Washington (Figure 1).[5]

The Big Bend is bounded to the north, west, and south by the circuitous course of the river, from its westward turn from a south-bound trajectory at the confluence with the Spokane River, to a brief northward turn at the confluence with the Grand Coulee, to its swing south-southeast from Pateros to Pasco where it is joined by the Snake and continues in a more orderly manner west through the Columbia Gorge to the Pacific. Deep and fertile sandy loam overlays much of the plateau's 12,780 square miles of land; deprived of water, the soil supports sage, mixed grasses, and an occasional crop of dryland wheat. Those who advocated Big Bend irrigation hoped instead to raise the more-profitable irrigated specialty crops of fruits, sugar beets, and truck produce, and to witness, and profit from, the rise of the towns that would inevitably follow and support the farmers (Figures 2 and 3).[6]

The Grand Coulee that opens over 500 feet above the bed of the Columbia was central to one of the two primary irrigation schemes proposed for the region. This hanging valley, marking an ancient flood path of glacial Lake Missoula, is 4 miles wide, bordered to the north, east, and west by cliffs approaching 900 feet, and extends south for 50 miles through the Big Bend. In 1892, editors of the *Coulee City News* first proposed a plan by which the Columbia River would be dammed, and its water diverted to the coulee from whence it would be delivered by canal and feeder ditch to 1,200,000 arid acres (Figure 4). Soon thereafter, Laughlin MacLean of Spokane, Washington introduced a competing plan by which over 2,000,000 acres at the southern and eastern extremes of the Big Bend and neighboring Palouse region would be irrigated by gravity flow from the Columbia, Spokane, or Pend Oreille rivers.[7]

---

[4] Within the United States, only the Mississippi River exceeds the Columbia River in volume. Although maximum recorded flow at the Grand Coulee Dam site is 489,000, the river is thought to have approached 725,000 cfs during the flood of 1894 ("Can the Columbia Be Controlled?", *Earth Mover*, June 1937).

[5] Paul Pitzer, *Grand Coulee. Harnessing a Dream* (Pullman, Washington: Washington State University Press, 1994), p. 1.

[6] Memorandum, Mead to Secretary of the Interior, December 27, 1934, Folder: Columbia Basin Project, Board and Engineering Reports on Construction Features, July through December 1934, Box 527, Decimal Classification 301, Project Correspondence File 1930-1945, RG 115, NARA-Den.

[7] Pitzer, *Grand Coulee*, pp. 6-10. The technological evolution of the "pumping plan" (as the Grand Coulee proposal came to be known) and the "gravity plan" (as the Pend Oreille storage and canal proposal came to be known); the series of state- and federally funded studies; the acrimonious debate between competing interest

(continued...)

By 1926, after considerable study and modification of the original proposals, officials with the Bureau of Reclamation reported publicly that while "the time will come when local and national interests will require the construction of [Columbia Basin Reclamation] works, and the utilization of these immeasurably valuable resources . . . this time has [not yet] arrived."[8] Privately, BOR Chief Engineer R.F. Walter argued that "the [Columbia Basin Reclamation] project must unquestionably be deferred for a very long time and the work to date has already covered the essential features of the project *sufficiently to indicate its difficulties and probable costs.*"[9]

By 1929, however, the Bureau of Reclamation (burdened by over-budget reclamation projects and bankrupt farmers unable to repay the cost of reclamation) was actively promoting construction of "multiple use" dams, whereby revenue from the sale of hydroelectric-power would cover part of the cost of reclamation (Figure 5).[10] Concurrently, Major John S. Butler of the United States Army Corps of Engineers (Corps) concluded that the Grand Coulee pumping plan was preferable to the Pend Oreille River gravity plan and that power sales would produce revenue "sufficient to return with interest the cost of the dam and power plant over a 50 year period (Figures 6 and 7)."[11] The Bureau of Reclamation agreed, noting that

---

[7](...continued)
groups; and the evolution from state funding of construction costs, to a state-federal partnership, to federal funding are not addressed in this construction history. Please see Pitzer, *Grand Coulee*; William D. Miner, "A History of the Columbia Basin Projects," (unpublished Ph.D. dissertation, Indiana University, 1950); Bruce Mitchell, *Flowing Wealth: The Story of Water Resource Development in North Central Washington, 1870-1950, Wenatchee Daily World*, March 6, 1967; Michael James Schulthesis, "The Struggle for Grand Coulee Dam — Beginnings" (unpublished master's thesis, Gonzaga University, 1961) for a detailed discussion of the early history of the Columbia Basin reclamation project. Federal reports relative to the Columbia Basin are cited and briefly described in the annotated bibliography that concludes this report.

[8] USDI Press Release, August 26, 1925, Folder: Col. Basin Eng. Gen., Oct 1924-September 1930, Box 415, Decimal Classification 791, Office of the Chief Engineer, Denver, Colorado, General Correspondence Files 1902-1942 (Engineering), Columbia Basin, RG 115, NARA-Den.

[9] R. F. Walter, Chief Engineer, to Dr. Elwood Mead, Commissioner, March 22, 1926, Folder: Col. Basin Eng. Gen. Oct. 1924-Sept. 1930, Box 415, Decimal Classification 791, Office of the Chief Engineer, Denver, Colorado, General Correspondence Files 1902-1942 (Engineering), Columbia Basin, RG 115, NARA-Den, emphasis added.

[10] James O'Sullivan to the Honorable Commissioner, Bureau of Reclamation, April 23, 1929, Folder: Col. Basin Eng. Gen, Oct. 1924-Sept. 1930, Box 415, Decimal Classification 791, Office of the Chief Engineer, Denver, Colorado, General Correspondence Files 1902-1942 (Engineering), Columbia Basin, RG 115, NARA-Den.

[11] R. F. Walter, Chief Engineer, L. N. McClellan, Electrical Engineer, E. B. Debler, Hydraulic Engineer, "The Columbia Basin Project, Washington, with Initial Development of the Quincy Unit" Bureau of Reclamation, September 30, 1931, Folder: Col. Basin Eng. Gen, Oct. 1930-Sept. 1931, Box 415, Decimal Classification 791, Office of the Chief Engineer, Denver, Colorado, General Correspondence Files 1902-1942 (Engineering), Columbia Basin, RG 115, NARA-Den.

> preliminary studies . . . indicate that if the power can be absorbed at the rate of 100,000 kilowatts per year, the revenue from sale of commercial power . . . would be sufficient to repay the cost of the dam with interest within 50 years and leave sufficient surplus revenues to repay a very substantial part of the cost of the initial irrigation development. . . . It appears that the output of the proposed installation of 1,575,000 kilowatts at the Grand Coulee power plant could be absorbed by the power market within economic transmission distance within 15 years.[12]

In 1932, the Bureau of Reclamation prepared preliminary plans for the "highest possible dam producing maximum power" at the Grand Coulee site — a dam 350' high with two power plants producing a combined 1,575,000 kilowatts and a pumping station to lift water from the 150-mile-long reservoir (Lake Roosevelt) to the Grand Coulee storage basin/equalizing reservoir. Including the irrigation and power distribution systems, project costs were estimated at $400,000,000. The Bureau of Reclamation would construct the project for the state, for which it would be reimbursed over a 50-year period (Figure 4).[13]

Immediately on the heels of this temporary victory for pumping-plan proponents, the Great Depression dramatically changed the project's cost-benefit equation. First, growth of the power-market — fundamental to the economic feasibility of the project — stalled. Second, newly elected president Franklin Delano Roosevelt approved and the Public Works Board granted $31,000,000 to the U.S. Army Corps of Engineers for initial design and construction of a navigation and power dam on the lower Columbia River at Warrendale, Oregon (Bonneville Dam), further saturating the power market. Finally, Arthur Hyde, Secretary of Agriculture (in company with the Washington State Grange and the *Farm Journal*), argued that

> [Agricultural plant] surpluses are at once the cause of low prices and our farm problem. . . . We need to <u>reduce</u> our present cultivated acreage by probably thirty or forty million acres. . . . The market is glutted with farm lands at depressed prices. There are no takers. It is plainly and indisputably against the interests of the farmers of Washington and of the adjoining States to undertake a project that would bring into production 12,000 more farms. . . . No farmer of the Northwest would, in his right mind, urge the Nation to undertake something that would add to already burdensome surpluses, depress prices of his products, reduce the value of his land, threaten his economic security, and lift huge sums out of the United States Treasury for the avowed purpose of agricultural expansion in an era when precisely the opposite policy is called for.[14]

---

[12] Walter, et al., "The Columbia Basin Project, Washington, with Initial Development of the Quincy Unit," pp. 2-10.

[13] "Grand Coulee Dam to Start Early in 1934," *Pacific Constructor*, August 19, 1933, p. 6; Pitzer, *Grand Coulee*, pp. 63-64.

[14] Arthur Hyde, Secretary of Agriculture, to the Board of Engineers for Rivers and Harbors, War Department, January 30, 1942. See also "Columbia Basin Folly" (editorial), *The Farm Journal*, April, 1932, V. 56, No. 4, p. 10 (continued...)

The economic depression, however, also dramatically increased the need for employment opportunities. President Roosevelt demurred on support of the $400,000,000 high dam and appurtenant irrigation works, suggesting instead a more modest low-power dam, with "less initial outlay and less power to be absorbed in the market," while still providing immediate construction jobs for as many as 12,000 local men. The high dam, allowing development of the irrigation program and of large blocks of commercial power, would be developed later.[15]

On April 26, 1933, after soliciting comment from BOR Chief Engineer R. F. Walter and Chief Design Engineer John L. (Jack) Savage, Mead reported that the Bureau could build a dam 145' high, with one power plant, for $60,000,000. Thus a project initially proposed (and most actively supported) by irrigation interests had been redefined, first as a maximum-yield power/irrigation project, and second as a low-power, make-work project "useful . . . for the immediate employment and materials and equipment market that they create."[16]

Although continuing to maintain that "no development of the land and water resources of the arid region equals this in importance and in the beneficial results which would come," Mead defended the President's decision and his agency's new project: "there is not at present a demand for these farms or for the crops to be grown on them."[17] On July 6, 1933, the Bureau of Reclamation and the Columbia Basin Commission, acting on behalf of the state of Washington, signed a contract whereby the Bureau would initiate $377,000 worth of preliminary work (including plans and survey), to be paid for from the state's $10 million relief fund. Cheered by over 5,000 people, and despite uncertainty over additional funding, the Columbia Basin Commission held ground-breaking ceremonies at the dam site on July 16. Eleven days later, the Public Works Board appropriated $63,000,000 for low-dam construction and on November 1, the state of Washington relinquished control of the project to the Department of the Interior/Bureau of Reclamation. On December 15, 1933 — prior to conclusive foundation studies and in the absence of a final dam design yet "in order to expedite the work to furnish early employment" — Goodfellow Brothers of Wenatchee, Washington, subcontractor under David H. Ryan, begin

---

[14](...continued)
and Pitzer, *Grand Coulee*, pp. 65-70.

[15] Mead, quoted in Pitzer, *Grand Coulee*, p. 70; Pitzer, *Grand Coulee*, p. 75.

[16] "Power, Navigation and Irrigation in Two Projects on the Columbia," *Engineering News-Record*, November 29, 1934, p. 678.

[17] Elwood Mead to Maj. General Lyle Brown, March 19, 1932, Folder: Col. Basin Eng. Gen, Oct. 1931-Sept. 1934, Box 415, Decimal Classification 791, Office of the Chief Engineer, Denver, Colorado, General Correspondence Files 1902-1942 (Engineering), Columbia Basin, RG 115, NARA-Den.

excavation on the west side of the river, clearing overburden from the granite bedrock abutment of the "First-Stage Low-Dam."[18]

First-Stage Low-Dam: Bureau of Reclamation Specifications No. 570

Drawing on "nearly six years of intensive research and study in connection with Boulder [Hoover] Dam," Bureau engineers in the Denver main office and at research laboratories in Fort Collins, Colorado experimented with 15 Grand Coulee dam designs, striving for a "safe and at the same time economical . . . structure" (Figure 8).[19] Their task was complicated by diversion and care of the Columbia River — the "most difficult engineering feat to be encountered" in construction — and by the unique economic and political concessions stipulating that the initial dam be superimposed by a subsequent structure, raising the dam to an ultimate height of 370' and an ultimate length of 4290'.[20] On December 1, 1933, Mead announced that Bureau engineers had concluded that they could not safely raise any of the hollow-core multiple-arch designs studied to

---

[18] "Eighteen U. S. Bureau of Reclamation Projects to Cost $218,440,000," *Western Construction News and Highway Builder*, January 1934, p. 5; Bureau of Reclamation, "Annual Project History, Columbia Basin Project," Vol. II, 1934, p. 77; Markhus, "Annual Project History, Columbia Basin Project," Vol. I, 1933, p. 9.

The Columbia River runs north at the dam site, a direction counter to its predominantly south and west run to the Pacific (and a direction largely masked by the complicated and circuitous road network to the site). "Left" and "Right" directional clues are given looking downriver (i.e. the Right Powerhouse is constructed on the east bank).

[19] Memorandum from Chief Designing Engineer J. L. Savage to Chief Engineer, re expedited program and winter program - Grand Coulee Dam, December 1, 1938, Folder: Columbia Basin, Dams and Reservoirs: Grand Coulee Dam, 1938, Box 535, Decimal Classification 301, Project Correspondence Files, 1930-1945, Columbia Basin Project, RG 115, NARA-RMR.

Jacob E. Warnock, Hydraulic Research Engineer for the Bureau of Reclamation, reported that "by the time the design and construction of the Grand Coulee Dam had been assigned to the Bureau of Reclamation, the practice of using hydraulic models as an aid in . . . design . . . was well established," having first been used in 1930 on the Cle Elum Dam, Yakima Project. At Grand Coulee, 1:15, 1:40, 1:120, and 1:184 full and partial scaled models constructed in Denver, Fort Collins, and Montrose laboratories informed design decisions re: scour at the toe of the overflow spillway, transverse wave and pool action; erosion of river bed; design of spillway training walls, crest, and drum gate; and river diversion. See "Models Guide Work on Western Dams; Found Indispensable in Design and Construction of Dams at Grand Coulee and Fort Peck," *Civil Engineering*, November, 1936; Jacob E. Warnock, "Experiments Aid in Design at Grand Coulee Dam," *Civil Engineering*, November, 1936, both in Folder: Columbia Basin, Dams and Reservoirs, Grand Coulee Dam, May 1935-December 1936, Box 535, Decimal Classification 301.1, Project Correspondence File 1930-1945, Columbia Basin Project, RG 115, NARA).

[20] Press Release, 12/17/1936, File: Correspondence re Construction of Coffer-Dams, Box 538, Columbia Basin Project, Project Correspondence File, 1930-1945, Decimal Classification 301.14, Entry 7, RG 115, NARA-RMR.

date and were instead concentrating on more-expensive "gravity-type dam sections" upon which a subsequent dam could be securely appended.[21]

On April 20, 1934 the Bureau issued invitations to bid on Specifications No. 570, a 145' concrete gravity dam. Plans for the diversion and care of the river were to be left to the contractor, subject to Bureau review and approval. Mason-Walsh-Atkinson-Kier (MWAK; Francis Donaldson, Chief Engineer), a four-company conglomerate, submitted a low bid of $29,339,301.50 and received official notice to proceed on September 25, 1934. Manley Harvey Slocum, "popular with working men . . .[yet with] little more than an eighth grade education and a troublesome penchant for heavy drinking" served as MWAK's construction superintendent: Slocum "knew how to build big things."[22]

Only three months later, the Bureau of Reclamation (in accord with many of their detractors and in resolution of an ongoing debate) concluded that the low dam was justified only as an economic-relief measure (with an indefensible man-hour to cost ratio). Mead and Walter further argued that the depth to bedrock and size (length) of the dam were both "too great in proportion to the head developed and . . . the cost involved in auxiliary features . . . [was] practically as much for the low dam as for the high dam; that the protracted drought had resulted in a mass exodus of farm families to the West, increasing the immediate need for reclamation of the Columbia Basin; that the hydraulic machinery in the power plant would of necessity be an uneconomical and unhappy compromise between the low and high head considerations; that construction of the high Grand Coulee dam, power plant, pumping plant, canals and laterals would provide employment for a "large number" of workers; and that the construction joint between the low and high dam had proved a "major engineering problem."[23]

---

[21] Anonymous, "Report of a conference held at the office of the Bureau of Reclamation, Denver, Colorado, December 2nd and 4th, 1933, concerning the Grand Coulee Project," n.d. (received Feb. 14, 1934), Folder: Col. Basin, Board and Engineering Reports, January 1, 1933-June 30, 1934, Box 527, Decimal Classification 301, Columbia Basin, RG 115, NARA-Den; Pitzer, *Grand Coulee*, p. 78.

[22] Silas H. Mason, Inc., Walsh Construction Co., Guy F. Atkinson Co., and the Kier Construction Co, composed MWAK. Six Companies of Washington, Inc. (affiliated with Six Companies, Inc., builders of Boulder [Hoover] Dam) submitted the unsuccessful high bid of $34,555,582. Pitzer, *Grand Coulee*, pp.99-101.

[23] Mead to R. K. Tiffany, Executive Officer, Washington State Planning Council, September 19, 1934, Folder: Col. Basin Eng. Gen, Oct. 1931-Sept. 1934, Box 415, Decimal Classification 791, Office of the Chief Engineer, Denver, Colorado, General Correspondence Files 1902-1942 (Engineering), Columbia Basin, RG 115, NARA-Den; Mead to Senator Clarence Dill, quoted in "Power, Navigation and Irrigation in Two Projects on the Columbia," *Engineering News-Record*, November 29, 1934, p. 682; Walter to Mead, December 15, 1934, File 301, Columbia Basin, Board and Engineering Reports on Construction Features, July through December 1934, Box 527, Project Correspondence File 1930-1945, Columbia Basin Project, RG 115, NARA.

Certainly, Mead had never fully supported the low-dam proposal (confessing that "I am not entirely happy at the change in plan. . . . I realize that we do not need the agricultural products at this time, but I believe we will in the near future. . . . It is a disappointment, therefore, to have the fruition of this dream indefinitely delayed"), nor had James O'Sullivan, Rufus Wood, Senator Clarence Dill, and other vocal supporters of the irrigation plan who had continued to argue for the greater social and economic benefits of the high dam. Moreover, the drought and depression had worsened, weakening the protests of the agricultural community while dramatically increasing the appeal of increased employment opportunities and raising the budgets, the stakes, and the public expectations of public-works projects.[24]

The Bureau's private correspondence reveals less hint, however, of substantial concern over the safety of the construction joint between the dams and little hint of the weight of this engineering concern in relation to the economic and political justification for construction of the irrigation project. As late as March 1934, Bureau engineers had reported that "in our opinion there is no doubt whatever that the enlargement, as contemplated, is an entirely feasible engineering undertaking."[25] In December 1934 memoranda to the Secretary of the Interior, Mead and his chief engineers urged construction of the high dam yet failed to mention construction difficulties associated with two-phase construction.[26]

Editors of *Engineering-News Record* effectively placed the engineering concerns within the larger context of a public-works "blunder," arguing that while the technical difficulties might be surmountable, the risk could not be justified in the face of the larger economic folly:

> When construction of the Grand Coulee power project . . . was undertaken more than a year ago, immediate re-employment was the dominant objective and the details and purpose of the project were given little thought. . . . As the facts are coming to be better understood, they rank Grand Coulee

---

[24] Elwood Mead to Roy R. Gill, Chairman, Executive Committee Columbia Basin Irrigation League, August 27, 1933, Folder: Columbia Basin Board and Engineering Reports, January 1, 1933-June 30, 1934, Box 527, Decimal Classification 301, Project Correspondence Files, 1930-1945, Columbia Basin Project, RG 115, NARA-RMR.

[25] "Bureau Board," quoted in W.C. Morse, Chairman Columbia Basin Commission's Consulting Board, A. F. Darland, D. C. Henny, Horace E. Smith, Columbia Basin Commission, to R. F. Walter, March 31, 1934, Folder: Col. Basin Eng. Gen, Oct. 1931-Sept. 1934, Box 415, Decimal Classification 791, Office of the Chief Engineer, Denver, Colorado, General Correspondence Files 1902-1942 (Engineering), Columbia Basin, RG 115, NARA-RMR.

"As contemplated," the design involved "the adoption of a downstream slope of the small dam of practically seven to ten . . . to be made coincident with the direction of the principal stress in the high dam under full water load . . . because along this plane no shearing stresses exist" (Morse et al. to Walter, March 31, 1934).

[26] Elwood Mead, J. L. Savage, L. N. McClellan, S. O. Harper, W. H. Nalder, B. W. Steele, to Secretary of the Interior, December 21, 1934; Mead to Secretary of the Interior, December 27, 1934; both in Folder: Columbia Basin Project, Board and Engineering Reports on Construction Features, July through December 1934, Box 527, Decimal Classification 301, Project Correspondence File 1930-1945, RG 115, NARA-RMR.

> definitely as the prime blunder of the public-works campaign. . . . The present Grand Coulee dam is not the one that was under study for years as part of the Columbia Basin irrigation project. . . . In short, the Grand Coulee project as it stands today is an economic error of first magnitude. And further, because of the mistaken decision to build the low dam, it is complicated by technical doubts not easily dismissed. . . . Raising [of the low dam], an operation of unprecedented dimensions, goes well beyond the range of recognized engineering procedure. While technical skills may overcome them, as it has overcome many other grave difficulties, *yet the hazard of the operation is one that should not needlessly be assumed.*[27]

On June 7, 1935, the Bureau and MWAK signed Change Order No. 1 "setting aside the original plans for a first-stage, or low-dam development, and in lieu thereof, authorized a contract for construction of the foundation for the high-dam and power plants." Change Order No. 1 stipulated completion of foundation excavation and river diversion; concrete placement to a maximum elevation of 1010 in the abutment sections and to elevation 945 in the spillway section; and powerhouse foundations to elevation 948. MWAK completed Change Order No. 1 on March 21, 1938 and turned the foundation over to new contractor Consolidated Builders Inc., composed of MWAK, Six Companies, Inc.,[28] contractor on Boulder Dam, and General Construction Co., contractor on Owyhee Dam.

Atop this foundation, Consolidated Builders Inc. would construct a straight, concrete-gravity central-overflow-spillway dam, 4,200' long, 550' high, 500' wide, composed of over 10,000,000 cubic yards of concrete. Sufficient concrete, BOR publicists said, to build a paved highway, 16' wide, from coast to coast (twice): the "Biggest Thing on Earth," "Larger than the Great Pyramid," "The 9th Wonder of the World." It became a source of both employment and carefully orchestrated public inspiration during a time of economic chaos and social disorder (Figure 9). Congressional passage of the Rivers and Harbors Act (Public Law No. 400, 74th Congress, H.R. 6732) formalized reclamation policy uniting power development with irrigation. It also "validated and ratified all contracts and agreements heretofore executed at Grand Coulee," assuring the legality and promising the continued funding of the $400,000,000 project.[29]

In the months prior to the change order, despite and in disregard for the continued private and public debate over final dam design, the Ryan Excavation contract continued, Lynch Brothers of

[27] Editor, *Engineering News-Record*, "A Mistake that Should be Corrected," *Engineering News-Record*, January 3, 1935, p. 23, emphasis added.

[28] Composed of Morrison-Knudsen, Co., Henry J. Kaiser Co., Utah Construction Co., J.F. Shea Company, McDonald and Kahn, Pacific Bridge Co.

[29] "Annual Project History, Columbia Basin Project," Vol. IX, 1941, p. 110; Pitzer, *Grand Coulee*, p. xi; "Grand Coulee Dam Columbia Basin Project Questions and Answers," September 1, 1936, in "Annual Project History, Columbia Basin Project," Vol. IV, 1936, pp. 354-360; Bureau of Reclamation, "Annual Project History, Columbia Basin Project," Vol. III, 1935, p. 94.

Seattle initiated core drilling at the foundation, and Rumsey and Company continued with testing of the area's gravel deposits. Assorted other contractors worked to bridge the Columbia River, to construct a water supply, to build two cities — one for government engineers, one for MWAK crews — to construct a haulage railroad from the Great Northern line at Coulee City, and to plan and construct trestles, gravel screening facilities, and other construction plant.[30] The politically and economically significant change from development of a low-head power project to construction of a massive high dam meant little to those engaged in the on-going construction effort. The low dam had simply been redefined as a foundation; the process of, and difficulties associated with, overburden excavation and river diversion and care remained unchanged. From a design perspective, the change was momentous: Bureau of Reclamation engineers were charged with designing a massive monolithic concrete structure of unprecedented proportions while realizing "maximum economy compatible with entire safety."[31] Upon completion of the final design, Chief Engineer Savage assured his construction engineer that

> Specifications no. 757 covering the construction of Grand Coulee Dam are, I believe, the best-considered specifications for a major dam that the Bureau, or any other organization, has prepared to date. These specifications utilize all of the comprehensive knowledge and data acquired from the Boulder [Hoover] project and, in addition, the most searching consideration has been given in their preparation to the fundamentals of safe design and construction (Figure 10).[32]

Work on the eight-year project proceeded in clearly defined stages, most identified as separate cost items within Specifications No. 570 (foundation) and Specifications No. 757 (high dam, power plant, and pumping station). Prior to cofferdam construction/river diversion, and as an immediate make-work measure, laborers under Specifications No. 557 cleared 2,000,000 cubic yards of unwatered, upper-elevation overburden from the east and west abutments. Core drilling and exploration and study of the quality and quantity in the Brett gravel pit proceeded apace with

---

[30] "Grand Coulee Development Becomes Federal Project," *Engineering News-Record*, March 22, 1934, p. 395; "Preliminary Construction Advances at Grand Coulee Dam," *Construction Methods*, August 1935, p. 30.

[31] Memorandum from Chief Designing Engineer J. L. Savage to Chief Engineer, re expedited program and winter program - Grand Coulee Dam, December 1, 1938, Folder: Columbia Basin, Dams and Reservoirs: Grand Coulee Dam, 1938, Box 535, Decimal Classification 301.1, Project Correspondence Files, 1930-1945, Columbia Basin Project, RG 115, NARA-Den; W. C. Morse, A. F. Darland, D. C. Henny, Horace E. Smith, Columbia Basin Commission, to R. F. Walter, March 31, 1934, Folder: 791, Col. Basin Eng. Gen, Oct. 1931-Sept. 1934, Box 415, Office of the Chief Engineer, Denver, Colorado, General Correspondence Files 1902-1942 (Engineering), Columbia Basin, RG 115, NARA.

[32] Memorandum from Chief Designing Engineer J. L. Savage to Chief Engineer, re expedited program and winter program - Grand Coulee Dam, December 1, 1938, Folder: Columbia Basin, Dams and Reservoirs: Grand Coulee Dam, 1938, Box 535, Decimal Classification 301.1, Project Correspondence Files, 1930-1945, Columbia Basin Project, RG 115, NARA-RMR.

dam design. Through 1937, cofferdam construction, excavation, foundation preparation, and concrete placement in the unwatered abutment areas dominated construction. On March 21, 1938, one year and 12 days ahead of schedule, MWAK completed Change Order 1. Concrete placement by new contractor Consolidated Builders, Inc. defined 1938-1939. Spillway, powerhouse, and pumping station construction was initiated and completed between 1939 and 1941. Finally, on June 1, 1942, during the peak of flood season, the Bureau of Reclamation staged a massive waterfall over the spillway, witnessed by an estimated 15,000 people and presented to the nation over a "coast-to-coast" radio broadcast.[33]

During the course of this construction, for the duration of the Great Depression, approximately 72,000 men found work at an average pay rate of $.86 per hour or $1,672 per year (Figures 11 and 12). As stipulated by the National Industrial Recovery Act, first preference in employment was given to qualified ex-service men with dependents; second preference to residents of the immediate project area; and third preference to residents of the state. This supply of labor proved "generally adequate" although "on occasion it was necessary to extend calls into neighboring states." Hours were worked in 7-hour shifts, run around the clock, with the remaining 3 hours of the day reserved for work inspections, equipment repair, and as insurance against overtime pay. These men, many with their families, lived in a scatter of makeshift construction camps or in MWAK's official company town, Mason City, located at the east abutment, on the other side of the river — and the other side of the tracks — from carefully designed, crafted and landscaped "Engineer Town" (Coulee Dam). Seventy-four men died between September 1933 and December 1941. Their deaths are tallied, but not described, in the Bureau of Reclamation's annual project reports, concluding in 1941 with a blunt assessment of the public benefits and the personal risk: "one fatality for every 776,438 man-hours worked or 1 fatality for every $1,944,926.68 spent."[34]

Manufacturing jobs throughout the nation were added to the economic benefits of direct employment at the dam site. By 1939, the BOR estimated that

> six eastern states . . . sold from a million to three and a quarter million dollars' worth of goods to the project; Minnesota and New Jersey sold nearly a million each; Iowa nearly half a million; and nine other States over two hundred thousand each. Three western states were large beneficiaries,

---

[33] "Three Big Dam Operations Begin in the Northwest," *Engineering News-Record*, April 15, 1934, p. 443; Markhus, "Annual Project History, Columbia Basin Project, Volume II, 1934, First Stage Development (Low Dam Power Project)" p. 92; "Annual Project History, Columbia Basin Project," Vol. X, 1942, p. 96.

[34] "Annual Project History, Columbia Basin Project," Vol. IX, 1941, p. 51; "Annual Project History, Columbia Basin Project," Vol. V, 1937, p. 72; "Preliminary Construction Advances at Grand Coulee Dam," *Construction Methods*, August 1935, p. 32; Karl Stoffel, "Grand Coulee Notes," *Excavating Engineer*, March 1934, pp. 152-153; "Annual Project History, Columbia Basin Project," Volume III, 1935, p. 64.

California through oil sales, Washington and Oregon by selling timber, and all three through their agencies for eastern manufacturers."[35]

EXCAVATION TO BEDROCK

Given the volume and length of the proposed Grand Coulee Dam, the suitability and strength of the foundation was of critical concern. An arched design, by which much of the total water load is carried to the abutments, was not "economically possible" at the Grand Coulee Dam site, where 4300' of river canyon divided the east and west abutments. All of the water load would be carried to the base of the structure.[36]

Between September 1933 and March 1934, Bureau of Reclamation contractors completed 45,000 linear feet of core drilling, developed "several" test shafts and trenches, and, under agreement with the U.S. Bureau of Mines, completed bedrock exploration, using electrical resistance readings for measurement of depth to bedrock. They found a fine-grained, "almost white to somewhat pinkish" granite and a coarser-grained, more massive granite, standing in what seemed to be almost vertical sheets confined to narrow lines of movement, and presenting a remarkably level surface.[37] BOR consulting geologist Charles P. Berkey concluded that this granite floor was "eminently capable of carrying . . . a great masonry structure of virtually whatever height other considerations may dictate" and placed the depth to bedrock at 60' to 170' below the normal low-water level of the river.[38]

An estimated 21,000,000 cubic yards of sandy silt, residuary river drift, and terraced gravels comprised these 60' to 170' of overburden (Figure 13). All would have to be excavated from the deep canyon prior to concrete placement and most displayed a tendency to slump when oversaturated, undercut, or subject to moderate changes in load or removal of normal support:

---

[35] USDI BOR Press Release, February 10, 1939, Folder: Columbia Basin, Dams & Reservoirs, Grand Coulee Dam, January 1939-December 1941, Box 534, Decimal Classification 301.1, Project Correspondence File 1930-1945, Columbia Basin Project, R.G. 115, NARA-RMR.

[36] Memorandum from Chief Designing Engineer J. L. Savage to Chief Engineer, re expedited program and winter program - Grand Coulee Dam, December 1, 1938, Folder: Columbia Basin, Dams and Reservoirs: Grand Coulee Dam, 1938, Box 535, Decimal Classification 301.1, Project Correspondence Files, 1930-1945, Columbia Basin Project, RG 115, NARA-RMR.

[37] Gilbert Darwin, "Grand Coulee Dam and Power Plant Specifications," *Western Construction News*, April 1934, p. 108; "New Record in Pouring Concrete," *Engineering News-Record*, July 15, 1937, p. 102.

[38] Markhus, "Annual Project History, Columbia Basin Project," 1933, pp. 80-81; Gilbert Darwin, "Grand Coulee Dam and Power Plant Specifications," *Western Construction News*, April 1934, p. 104; Charles P. Berkey, ASCE, "Foundation Conditions for Grand Coulee and Bonneville Projects," *Civil Engineering*, February 1935, pp. 68-69.

> once disturbed [the ultra-fine rock-flour glacial silt ground by the ice sheets] is unstable on any slope steeper than 4 to 1 even when comparatively dry. . . . When moistened and disturbed the material takes on the consistency of axle grease. When dry and pulverized it forms an impalpably fine dust.[39]

This tendency to slide would haunt excavation, cofferdam-construction, and tailrace-channel development, lending weight to construction engineer Bank's assessment that "the vast amount of excavation that must be done and the task of diverting the river," defined the "major and unusual" problems associated with Grand Coulee Dam construction.[40]

Like river diversion (see below), Bureau engineers defined overburden excavation and the danger of slides as "a real construction problem" yet of insufficient consequence to threaten the feasibility of the project: "after the excavation is completed and the dam established, it ceases to be of serious moment as far as the main structure is concerned." Methods of overburden removal (and, similarly, cofferdam construction), were thus largely the concern of the general contractors and their insurance underwriters.[41]

Following award of the contract for low-dam/foundation construction (and in rejection of the expected and traditional truck-haul operation), MWAK construction engineers designed a large (60"), high-speed (620' per minute), large-volume (2500 cy per hour) belt conveyor, equipped with four- and five-yard electric shovels and 10- to 24-yard dump carts. Three to five tributary conveyors converged at a central hub where a surge feeder discharged the accumulation of "muck" into the main conveyor (Figure 14). Placed in operation on December 13, 1934, the conveyor system ran to a spoil dump in Rattlesnake Canyon, 425' higher and 1 1/4 mile east of the damsite. Work proceeded under huge floodlights, at a 24-hour average excavation rate of 52,000 cubic yards. By 1935, over a million cubic yards had been relocated and headlines proclaimed: "A Mountain has been Moved a Mile."[42]

---

[39] Grant Gordon, Associate Engineer, U.S.B.R, "Freezing Arch Across Toe of East Forebay Slide, Grand Coulee Dam," n.d., CB510.00, Engineering & Research Center Project Reports 1910-1955, Box 319 (old box 356-357), RG 115, NARA-RMR.

[40] F. A. Banks quoted in "Can the Columbia Be Controlled?," *Eorth Mover*, June 1937.

[41] Charles P. Berkey, ASCE, "Foundation Conditions for Grand Coulee and Bonneville Projects," *Civil Engineering*, February 1935, pp. 68-69.

[42] "Annual Project History, Columbia Basin Project," Volume III, 1935, pp. 99, 152, 159; Karl Stoffel, "Grand Coulee Notes," *Excovoting Engineer*, March 1934, pp. 152-153; Charles H. Carter, "Change in Plan for Grand Coulee Dam Explained by Engineer," *Southwest Builder and Controctor*, August 23, 1935, n.p.; "Preliminary Construction Advances at Grand Coulee Dam," *Construction Methods*, August 1935, p. 30; Quoted in "Can the Columbia Be Controlled?," *Eorth Mover*, June 1937, n.p.

The short haul and gentle grade on the east side of the dam site facilitated overburden removal: a 30' roadway was located on a uniform 5 percent grade. over which a fleet of trucks hauling material approximately

(continued...)

First in January, then March, then April, and again in November 1934, the overburden confirmed its tendency to slump, with extensive slides on both sides of the river. By 1936, contractors had relocated the railroad and highway, had excavated an additional 1,000,000 cubic yards of unstable overburden, and had dewatered the west forebay and tailrace slopes through a series of drainage wells and shafts.[43]

Of equal concern was the east-side slide initiated in March, 1936 (Figure 15). Protected by the east-bank cofferdam, MWAK had exposed bedrock to elevation 850, had completed excavation of the tailrace slope, and had excavated the forebay slope to elevation 900. Here, conforming to test-drill results, they found a long narrow gulch, parallel to the river near the axis of the dam, that extended 120' below the average bedrock level. Soon after crews exposed bedrock in the bottom of the gulch, a large portion of the forebay slope gave way and slid to a slope of 2:1. When work at the site resumed in August (after the standard flood-water hiatus), the 200,000-cy slide resumed, at an average rate of 2' per hour. Excavation within the east-bank unwatered zone while the slide remained active "invited disaster"; to flatten the forebay slopes until stable would be expensive and time consuming; and the dispersed nature of water seepage precluded drainage.[44]

Faced by this "critical emergency," BOR engineers "achieved an unprecedented solution" (or "expedient") that allowed continued construction at a tolerable cost.[45] Drawing roughly[46] on the method of F. H. Poetsch of Prussia, who had used frozen earth in sinking deep shafts, Bureau engineers erected an ammonia-brine refrigeration system in a galvanized sheet-iron building constructed above the slide (Figures 16 and 17). Using an existing concrete-arch dam and timber-crib support (constructed by MWAK when they reached bedrock and overrun soon thereafter by the slide) as a base, engineers defined an "arch" of earth through placement of 3" freezing coils. Between August and September the earth was frozen, restraining the sliding material long enough

---

[42](...continued)
4,500 feet upstream to the spoil dump.

[43] Bureau of Reclamation, "Annual Project History, Columbia Basin Project," Vol. II, 1934, pp. 10, 37; "Annual Project History, Columbia Basin Project," Vol. 5, 1937, p. 126; "Preliminary Construction Advances at Grand Coulee Dam," *Construction Methods*, August 1935, p. 30.

[44] "Annual Project History, Columbia Basin Project," Vol. 3, 1936, pp. 176-177.

[45] BOR, as quoted in USDI BOR, Press Release, December 7, 1936, Folder: Columbia Basin, Dams & Reservoirs, Grand Coulee Dam, May 1935-December 1936, Box 535, Decimal Classification 301.1, Project Correspondence File 1930-1945, Columbia Basin Project, R.G. 115, NARA-RMR.

[46] "No criteria existed from former frozen arches. The only information available about similar operations was meager and offered little that could be used (" Grant Gordon, Associate Engineer, U.S.B.R, "Freezing Arch Dam Across Toe of East Forebay Slide, Grand Coulee Dam," n.d., CB510.00, Engineering & Research Center Project Reports 1910-1955, Box 319 (old box 356-357), NARA-RMR.

to remove the desired overburden and to place concrete to sufficient height to protect the dam from subsequent slides. In April, 1937, following record-breaking concrete-placement efforts during low water, the ice plant was removed and the void between the slide and the east abutment filled "as an assurance against further hazard from the slide."[47]

Against the cost of the frozen arch, the Bureau credited a direct savings of $30,000, associated with removal of a minimum of 30,000 cubic yards — "a small fraction of what would certainly slide" — and estimated total savings in time and excavation at two months and $200,000. Despite the economic victory, Bureau engineer Grant Gordon was cautious about defining the dam as a significant construction method: "It is difficult to imagine a duplication of conditions which would ever make a scheme exactly like this feasible again. Its interest then, lies chiefly in its being unique."[48]

ITEM 1, SPECIFICATIONS NO. 570: "DIVERSION AND CARE OF RIVER"

United States Geological Survey (USGS) river readings, taken between 1913 and 1933 revealed that the Columbia River at the dam site normally varied in flow from 17,000 to 500,000 second feet, a volume that prevented construction of diversion tunnels (as at Boulder and Shasta dams). The river had to be diverted through open channels of ample size to pass the maximum anticipated floodwater. Maximum volume could be anticipated during May to August, with peak flows in June; between September and April, the river rarely exceeded 100,000 cfs. Prior to diversion of the river and unwatering of the foundation, this seasonal schedule defined the parameters of dam construction.[49]

Dismissing construction of a new river channel as needlessly expensive, and after consultation with Bureau and consulting engineers, MWAK construction engineers proposed four cofferdams, constructed in three stages and designed to "turn . . . [the river] to one side of the canyon for the construction of half the dam and then diverting [it] . . . back through openings left in the dam, for construction of the other half."[50] The first cofferdam, an 800' wide, 115' tall cellular steel-sheet structure running for 1/2 mile parallel to the west bank of the river near the low-water line, unwatered 9,000,000 cy and 68 acres at the west abutment. The smaller cofferdam on the east bank of the river, constructed first of earth (1934-1935) and then of timber, was of sufficient height and strength to unwater the east abutment for nine months of the year, or until the river discharge reached 200,000 second feet and compelled abandonment of the excavation area.

[47] "Annual Project History, Columbia Basin Project," Vol. 5, 1937, p. 45.

[48] Gordon, "Freezing Arch Across Toe of East Forebay Slide, Grand Coulee Dam."

[49] Bureau of Reclamation, "Annual Project History, Columbia Basin Project," Vol. 2, 1935, p. 111.

[50] "Three Big Dam Operations Begin in the Northwest," *Engineering News-Record*, April 15, 1934, p. 444.

During the final diversion stage, two cross-channel dams forced the river sharply west just upstream of the dam, where it flowed through four slots left in the west abutment of the dam before returning to its course (Figure 18).[51]

On January 1, 1935, MWAK crews drove the first sheet piling of the west-side cofferdam, "therewith beginning construction of the greatest, or at least the largest, river control structure thus far undertaken by the construction industry" (Figure 19).[52] Although construction techniques varied slightly between the ten distinct cell groups (A-J), the cofferdam was generally of steel construction, cross-tied to timber framing with steel rods. Gravel, taken from excavation operations at the west abutment and conveyed to the cofferdam by shuttle conveyor, filled the circular 40' space between the front and back walls of each cell (Figure 20). Cell groups E and F were permanent, constructed of concrete and ultimately incorporated within block 40 of the Grand Coulee Dam. Cell group "clusters" D and G would tie to the cross-river cofferdams.[53]

To construction engineers and the men charged with cofferdam construction, size translated to a variety of problems, including transport of 18,000 tons of steel to the dam site prior to completion of the construction railroad and driving of 3,000 linear feet of steel pile to bedrock, through non-receptive compact glacial till.[54] Surprised by the difficulty of reaching bedrock, and racing cofferdam completion prior to May floodwaters, MWAK modified their original construction plan to include use of four pile drivers, rather than one, at each of the 10 cofferdam cell groups. A tower gantry with 70' base, sufficient to span the cell structure, was supported on trestles constructed on either side of the cofferdam. This gantry provided full coverage via two movable 36" I-beams that spanned the structure and carried geared trolley hoists from which McKiernan-Terry pile hammers were suspended. Although "the tower gantry improved efficiency about 50 per cent and decreased the cost as compared with single hammers handled by long-boom hoisting rigs" the refusal point through the compact till remained at 40' to 65', considerably above bedrock. To provide adequate drainage and prevent excessive saturation of the clay, fifteen wells (paired with electric pumps) were constructed at 100' intervals along the inner berm.[55] Forced to improvise more dramatically at the "river section" of the cofferdam (cell-group E), MWAK engineers modified the original construction plan to provide

[51] Inland Steel clipping, n.d., Folder: Correspondence re Construction of Coffer-Dams, Box 538, Columbia Basin Project, Project Correspondence File, 1930-1945, Decimal Classification 301.14, Entry 7, RG 115, NARA-RMR; "Annual Project History, Columbia Basin Project," Vol. II, 1934, p. 78; "Annual Project History, Columbia Basin Project," Vol. III, 1935, pp. 99, 111.

[52] "Annual Project History, Columbia Basin Project," Volume III, 1935, p. 99.

[53] "Annual Project History," Columbia Basin Project, Volume III, 1935, p. 99.

[54] Bureau of Reclamation, "Annual Project History, Columbia Basin Project," Vol. 2, 1935, p. 115.

[55] "Annual Project History, Columbia Basin Project," Vol. III, 1935, p. 117-120.

> a berm about 60 ft. wide between the inside of the coffers of the river section and the face of the excavation for the permanent concrete to be poured in the west cofferdam. . . . To accomplish this result a type of construction was used which required the placing of vertical needle beams with a three-segment timber arch between them. The essential feature of this design is that it will hold back the pressure of the material behind and allow prestressing of the supporting members of the pit while preventing any movement of the material. The method had been used previously in New York subway construction.[56]

High water came two-weeks early in 1935 and its peak of 344,000 cfs in June was 32' higher than normal. It found the clay as difficult to penetrate as had the piledrivers; save for a slow seep of 200 to 600 gallons per minute, removed by pump, the cofferdam held.[57]

One year later, in August 1936, MWAK crews began construction of the rock-filled timber-crib cross-stream cofferdams. Sections of dam were constructed on shore, floated into place and sunk with rock fill. In December, the last stop logs were put in place and "the cofferdam received the full force of the river, which it turned aside."[58] Four months later, long after the jubilant celebrations over the river's successful diversion and two short months prior to maximum runoff, a leak developed in the west-side cofferdam at cell groups F and G, the "cloverleaf" where the west cofferdam/dam foundation formed a junction with the downstream cross-river cofferdam (and the unfortunate location of one of the towers carrying sand and gravel to the west-side mixing plant [see below]). By morning of March 18, 1937, small leaks noted on the previous evening had increased, appearing as jets through openings in the steel piles of cells F-8 and F-9 (Figure 21).[59] Near noon, a sheet piling between F-9 and G-3 opened, releasing the sand fill and 30,000 gallons of water per minute while threatening to flood the entire enclosure and to undermine the central conveyor tower. In a desperate and improvised effort to avoid "disastrous delay" (and in striking low-tech contrast to the high-tech, carefully planned, construction effort), MWAK crews created an earth- and rock-fill crib outside the apparent source of the leak at cell G-5, in which they dumped straw, tumbleweed, sagebrush, clay, mattresses, sandbags, and fir-tree

---

[56] "Coulee Cofferdam, Sheetpile Cells Driven by Gantry Carrying Four Hammers," *Construction Methods*, September 1935, pp. 42-44.

[57] Pitzer, *Grand Coulee*, pp. 109-110.

[58] Press Release, 12/17/1936, Folder: Correspondence re Construction of Coffer-Dams, Box 538, Columbia Basin Project, Project Correspondence File, 1930-1945, Decimal Classification 301.14, Entry 7, RG 115, NARA-RMR.

[59] Day letter, J. H. Miner to Reclamation Denver, March 18, 1937, Folder: Correspondence re Construction of Coffer-Dams, Box 538, Columbia Basin Project, Project Correspondence File, 1930-1945, Decimal Classification 301.14, Entry 7, RG 115, NARA-RMR.

mats.[60] With the flood slowed, MWAK drove steel sheet pilings to support sand and gravel designed to disperse the flow of water from the ruptured cell group. Grout holes within this fill were injected first with sand, sawdust, wood shavings, and finally with cement, water, and bentonite — its first application on the project. By late April, the leak had slowed to 250 gallons per minute and financial catastrophe had been averted.[61]

By August 1937, the dam had risen to sufficient height for removal of the upper portions of the disposable cofferdams. During subsequent construction, and prior to completion of the spillway, eight large portable (and temporary) gates, 52' wide and 35' high, controlled the passage of water through the diversion slots left in the dam foundation (Figure 22).

CONCRETE PLACEMENT

> *Can every portion of such a tremendous mass of concrete be built into a monolithic structure that will not crack longitudinally and thus weaken a structure that is dependent for safety on its monolithic character? . . . If Grand Coulee Dam should fail, it would probably be due to shear failure along vertical longitudinal cracking that had destroyed the integrity of the monolithic structure. It is this consideration that makes so exceedingly important the construction of a dam that will not develop the characteristic vertical cracks that have been observed on less important dams designed and constructed prior to Boulder Dam.*[62]

Diversion of the river from its course and excavation of the overburden and rock left in its wake was a task of gross proportions, realized with equipment of startling size: four-and five-yard electric shovels, ten- to 24-yard dump carts, stiffleg derricks, revolving cranes, crawler cranes, electric whirleys. . . . In contrast, engineers described foundation preparation as a "manicure," a meticulous, detailed process by which bedrock was picked and scoured clean.

Natural seams and pockets were cut from the bedrock surface, allowing adequate bearing of concrete on granite. With a base width of 500' and a length of over 4,000' (including the massive abutments), the expanse of concrete/granite contact totaled 2,000,000 square feet, each of which was cleaned with hand picks and paving breakers to remove "all loose, fractured, soft, or disintegrated rock (Figure 23)." The foundation was then sandblasted to removed calcium

---

[60] J. H. Miner, Acting Construction Engineer, to Chief Engineer, March 20, 1937, Folder: Columbia Basin, Correspondence Re: Construction of Cofferdams, Box 538, Decimal Classification 301.14, Project Correspondence Files, 1930-1945, Columbia Basin Project, RG 115, NARA-RMR.

[61] "Annual Project History, Columbia Basin Project," Vol. 5, 1937, p. 108.

[62] Memorandum from Chief Designing Engineer J. L. Savage to Chief Engineer, re expedited program and winter program - Grand Coulee Dam, December 1, 1938, Folder: Columbia Basin, Dams and Reservoirs: Grand Coulee Dam, 1938, Box 535, Decimal Classification Project Correspondence Files, 1930-1945, Columbia Basin Project, RG 115, NARA-RMR.

deposits, "thoroughly cleaned" by brushing with high velocity jets of air and water, and dried with sponges and air siphons. The operation, "rather accurately described as `manicuring,' cost about 75 cents per square foot."[63]

What preliminary core drilling had suggested was a "remarkably flat" granite foundation, overburden removal revealed to be remarkably contoured and irregular, particularly at the east abutment and along a lift seam near the center of the west foundation area. As bedrock was scaled along the axis of the dam, crews equipped with percussion drills and pneumatic jackhammers injected cement grout (cement and water) at low pressure (200 psi) into rock crevices and 682 grout holes (ranging in depth from 20' to 200'), hoping to create a curtain impervious to percolation or uplift. "The adopted procedure consisted of injecting the greatest possible quantity of grout of varying water-cement ratios under pressure in the shortest period of time, keeping the hole open as long as possible."[64]

On December 6, 1935, Washington governor Clarence Martin poured the ceremonial "first" of over 10,511,160 cubic yards of concrete at Grand Coulee, an event marked with remarkable pomp and circumstance and great public discussion of the enormity of the task ahead. Specifications for aggregate composition, drytime, concrete cooling, surface preparation, and joint adhesion for each of these ten million yards were exacting and enforced by government inspectors working around the clock: the maximum difference in elevation of any two adjacent panels of concrete was not to be greater than 15' perpendicular to the axis of the dam or 30' parallel to the axis of the dam; concrete was to be cooled to 45°, attainable only with a period of winter cooling; to facilitate concrete cooling and contraction-joint grouting, all panels in the areas separated by transverse construction joints were to be kept at a uniform elevation; within a block, no more than 5 feet of concrete ("5-foot lift) were to be placed in a 72-hour period; concrete, when poured, was not to exceed 85° or to drop below 40°; concrete placement was to stop during the winter months, unless these temperatures could be maintained through steam-heating.[65] In response to contractors' requests to relax these restrictions, thereby speeding construction, BOR engineers Walter, Banks, Savage, McClellan, and Hammond argued:

---

[63] "Annual Project History, Columbia Basin Project," Vol. V, 1937, p. 153; "New Record in Pouring Concrete," *Engineering News-Record*, July 15, 1937, p. 102; "Annual Project History, Columbia Basin Project," Vol. VI, 1938, p. 230.

[64] Chief Engineer to Supervising Engineer, July 15, 1939, Folder: Col. Basin, Engineering Consulting Board, May 1939-May 1940, Box 417, Decimal Classification 791-1, Office of the Chief Engineer, Denver, Colorado, General Correspondence Files 1902-1942 (Engineering), Columbia Basin, RG 115, NARA-RMR; "Annual Project History, Columbia Basin Project," Volume III, 1935, pp. 176-177.

[65] Walter, Banks, Savage, McClellan, and Hammond to the Commissioner, December 12, 1938, Folder: Columbia Basin, Dams and Reservoirs: Grand Coulee Dam, 1938, Box 535, Decimal Classification 301.1, Project Correspondence Files, 1930-1945, Columbia Basin Project, RG 115, NARA-RMR.

> the restrictions and provisions of the specifications were not placed there as nuisances to impede construction progress, but on the other hand, were after careful deliberation, based on scientific study and experience, included in the specification to insure that a safe and durable structure would be the result. As between a safe dam and speedy construction, if both can not be obtained, there should be no argument.

Design of a rapid and efficient construction plant, operating within the parameters of a cautious and temperate construction methodology, was thus critical to the economically viable construction of the "largest structure ever built by man."[66]

In June 1934, after a year of study,[67] the Bureau of Reclamation recommended the Brett gravel pit as the best source for concrete aggregates, adequate to supply over 9,000,000 cy of gravel; in contrast to other remote western dams (e.g. Shasta), where delivery of quality concrete aggregate over long distances to the construction site represented a significant construction cost, the Brett deposit was "advantageously situated" a mere 2 miles east and 700' above the dam site.[68] An elaborate screening and washing plant was constructed below the gravel pit (Figures 24 and 25).[69]

A suspension bridge connected the screening plant with the Westmix plant, transporting aggregate westward by conveyor belt. The bridge crossed the canyon in two 1,437' spans, supported by a 325' steel tower secured to the west cofferdam (at cell group G), creating "a

---

[66] Pitzer, *Grand Coulee*, p. 132; Annual Project History, Columbia Basin Project," Vol. IX, 1941, p. 110.
Technical testing and analysis of concrete were handled by the Concrete Control Department, headed by the Concrete Technician who reported to the Field Engineer. The main divisions of activity included "gravel pit inspection, control of concrete manufacture, pozzolanic investigations, and laboratory operations incidental to concrete control and related features." Three-shift inspection was carried on by a small group of technicians who inspected dam and power house concrete placing (and also supervised concrete cooling operations and control). At the Brett gravel pit and the gravel processing plant, inspectors were on duty "as needed" ("Annual Project History, Columbia Basin Project," Volume III, 1935, p. 85; "Annual Project History, Columbia Basin Project," Vol. V, 1937, pp. 77-78).

[67] Bureau engineers, working from a "very complete" testing laboratory in the basement of the main Denver office, tested and graded concrete aggregate: "solid concrete cylinders as large as 3' in diameter are here tested to destruction in order to determine the characteristics of concrete made with various aggregates" (Anonymous, "Report of a conference held at the office of the Bureau of Reclamation, Denver, Colorado, December 2nd and 4th, 1933, concerning the Grand Coulee Project," n.d. (received Feb. 14, 1934), Folder: Col. Basin, Board and Engineering Reports, January 1, 1933-June 30, 1934, Box 527, Decimal Classification 301, Columbia Basin, RG 115, NARA-RMR).

[68] Bureau of Reclamation, "Annual Project History, Columbia Basin Project," Vol. II, 1934, p. 12.

[69] See "Annual Project History, Columbia Basin Project," Vol. III, 1935, pp. 179-200 for a detailed discussion of gravel excavation, cleaning, screening, and storage.

spectacular finished assembly" (Figure 26). A simple timber trestle, approximately 1,500' in length, conveyed aggregate to the Eastmix plant.[70]

Fifty-thousand barrels of cement, sufficient for 45,000 cy of concrete, could be stored and blended at a plant 1/2 mile southwest of the dam, near the railroad tracks. After mixing "various brands of cement in desired quantity" (formulas based in part on extensive BOR research and testing of pozzolanic admixtures and concrete strength), cement was conveyed to the Eastmix and Westmix plants through pneumatic pipe, at a rate of 1000 barrels an hour, traveling over 100 miles per hour.[71]

Those charged with placing an unprecedented volume of concrete at an unprecedented rate christened the Westmix plant the "House of Magic." Pneumatic pipes delivered cement to bins near the top of the 126' building, via a de-aerating tank, and the suspension-bridge conveyor belt delivered sand and gravel to a series of grade-specific bins located directly under the roof. Beneath the bins, organized in a "concentric zone design" whereby materials flowed toward the center of the plant, was the "Brain Chamber of the House of Magic," housing the dispatcher and batcher control rooms. Johnson automatic batch weighers, equipped with weigh-beams and selector air valves, weighed the seven different ingredients of concrete.[72] From the batchers, material was conveyed by central hopper and swivel chute to one of four 4-yard 75-horsepower Koehring mixers where mixing time (improved from three minutes to two minutes over the course of the project) was automatically controlled and "interlocking mechanisms" held each operation to its "proper sequence" (Figure 27). From mixer, to conical hopper, to 4-yard placement buckets carried on flat cars of the elevation 1024 trestle, took an average of 25 seconds. The BOR's publicity department lauded the entire plant as a striking example of the economic savings associated with small efficiencies, employing BOR engineers' design improvements to the mixer blades as an example: "only a minute saved per batch, but a great savings made in the total time required for mixing - over two and a half million minutes on the job - half a year."[73]

---

[70] "Aerial Belt Delivers Aggregate Across Columbia River," *Construction Methods*, December 1935, p. 48; Bureau of Reclamation, "Annual Project History, Columbia Basin Project," Vol. III, 1935, pp. 183, 204, 215; "Preliminary Construction Advances at Grand Coulee Dam," *Construction Methods*, August 1935, p. 32.

[71] "Annual Project History, Columbia Basin Project," Vol. III, 1935, p. 214.

[72] Under the heading of special work, The BOR's concrete-control division had studied pozzolanic materials since 1934. In August, 1937, pozzolanic material, replacing 25 percent of the modified Portland cement, was used in five batches of 6" maximum mass concrete placed in the dam. By December pozzolanas were preblended with Portland cement ("Annual Project History, Columbia Basin Project," Vol. 5, 1937, p. 79).

[73] USDI BOR, Press Release, January 19, 1939, Folder: Columbia Basin Dams and Reservoirs, Grand Coulee Dam, January 1939-December 1941, Box 534, Decimal Classification 301.1, Project Correspondence File 1930-1945, Columbia Basin Project, RG 115, NARA-RMR; "Annual Project History, Columbia Basin Project," Vol. III,
(continued...)

The Bureau of Reclamation described the method of transporting and placing concrete:

> Concrete trains, composed of a 10-ton Diesel-electric locomotive, and a flat car carrying four buckets . . . were pulled in under the mixing plant and the buckets were loaded directly from the discharge hopper. The cars were then hauled to the desired point on the trestle where the buckets were picked up by [gantry] cranes and lowered to the blocks in the dam as required (Figure 28).

During foundation construction, a trestle at elevation 1024 (14' above maximum height of the foundation) supported the gantry cranes. As the dam rose in height, CBI constructed a new trestle at elevation 1180, of sufficient width for four standard-gauge railroad tracks and on which larger and improved gantry cranes with a working span of 350' assured coverage of all but the right and left abutments. At the abutments, the contractor established stationary Lambert stiffleg derricks, for placement of concrete in the area beyond the trestle and outside the working range of the trestle cranes. With construction of this new trestle, both the east and west mix plants were re-assembled on the east bank of the river at elevation 1180, allowing removal of both the elevation 1024 trestle and the suspension-bridge conveyor (Figure 29).[74]

Four-yard bottom-dump buckets released concrete for placement, first on "manicured" bedrock and finally on sequential blocks that formed the vertical tiers of the dam (Figure 30). These tiers varied in size from 50'x50' in the spillway area to 25'x34' in blocks opposite the powerhouses; many were traversed by octagonal penstock tunnels, outlet tubes, or interior galleries. Vertical and horizontal keys at the transverse and longitudinal joints "locked" each tier to its neighbor (Figure 31). In a meticulous process akin to preparation of bedrock, existing concrete surfaces, cured a minimum of 72 hours, were sandblasted clean prior to each successive pour. The wood placement forms were removed, areas of porous or fractured concrete (as identified by Government inspectors) carefully removed with chipping hammers and filled with a mortar patch, and all cooling, grouting, and drainage pipe placed.[75]

Concrete was cooled to 45°, through a process first tested at Oregon's Owyhee Dam and first implemented at Boulder (Hoover) Dam: 2 to 4 gallons per minute of river water were piped through 2,116 cooling coils embedded in the concrete at 38 strategic cooling zones. This process was completed in two stages, first immediately after the concrete pour, and again during the

---

[73](...continued)
1935, pp. 215-220.

[74] "Annual Project History, Columbia Basin Project," Vol. VI, 1938, pp. 120-129, 136-137; "New Record in Pouring Concrete," *Engineering News-Record*, July 15, 1937, p. 102.

[75] "Annual Project History, Columbia Basin Project," Vol. VI, 1938, pp. 230-231.

winter when Columbia River water dropped sharply below its summer average of 55°.[76] After final cooling, contraction joints between the vertical tiers were grouted though a pipe distribution system embedded in the concrete as it was being poured, "thus forming a solid monolithic structure."[77] On the heels of the successfully improvised repair of the west-cofferdam leak (and in one of many Grand Coulee examples of the engineering maxim that "technical decisions [do] not always arise from scientifically optimizing studies") this grout was changed in October 1936 from Portland cement and water to a mixture of Portland cement, calcium chloride (to speed the curing process), and bentonite (to improve adhesion).[78]

By 1939, concrete placement at Grand Coulee proceeded at an astonishing pace, breaking the monthly and yearly records established by MWAK during foundation construction and culminating on May 25, 1939 with a carefully planned and well-publicized single-day world-record pour of 20,684.5 cubic yards.[79] CBI and the Bureau of Reclamation had reduced the volume of concrete laid during the previous week, thus assuring that much of the dam's surface was sufficiently cured for a new layer. The press was alerted, and at midnight CBI crews began placing concrete at a rate of one cubic yard every 4.18 seconds. The feat was never accomplished — or attempted — again and was incidental (if not detrimental) to the dam's design and subsequent use. It did, however, testify to the phenomenal capacity of the construction plant and added to the BOR and CBI's growing list of "fastest, greatest, biggest" accomplishments associated with Grand Coulee Dam.[80] On November 10, 1940, CBI suspended concrete placing for the duration of the winter, with a mere 33,000 cy (3 percent) remaining to be placed in the spillway bridge, elevator towers, sidewalks and parapets, and gate-guide extensions for the outlet works (Figure 32).

---

[76] "Annual Project History, Columbia Basin Project," Vol. V, 1937, p. 158; "Annual Project History, Columbia Basin Project," Vol. VI, 1938, p. 242;"Annual Project History, Columbia Basin Project," Vol. IX, 1941, p. 111.

As the dam neared completion, the BOR approved an accelerated cooling program of the spillway, elevation 1100 to 1225, to allow installation of the drum gates prior to winter. CBI constructed an atmospheric cooling tower with an output of 5,500 gallons per minute. Barge #6 being pumped water to the tower where it was diverted to the spillway area and the adjacent abutment cooling zones ("Annual Project History, Columbia Basin Project," Vol. VIII, 1940, p. 131).

[77] "Annual Project History, Columbia Basin Project," Vol. 3, 1936, p. 355.

[78] Dr. David Billington, personal correspondence with Ann Hubber, August 1, 1997; "Annual Project History, Columbia Basin Project," Vol. 5, 1937, p. 152.

[79] In contrast, the previous record of 15,000 cy, established by MWAK crews during foundation construction, had exceeded the previous record of 10,417 cy, established by Six Companies, Inc. at Boulder Dam ("All Records for Concreting Broken in Building Base for the Grand Coulee Dam," *Southwest Builder and Contractor*, January 28, 1938, n.p.).

[80] Pitzer, *Grand Coulee*, pp. 204-205.

SPILLWAY

Optimal head for power generation and the anticipated needs of downstream irrigators dictated the minimum height of Grand Coulee Dam. The absence of an international treaty whereby water backed by Grand Coulee Dam could cross to Canadian soil dictated the maximum height: a reservoir level reaching no higher than elevation 1290 would extend 151 miles to the border. Within the central overflow spillway specified for the dam, 11 regulating drum gates (manufactured by the American Bridge Co.) maintain the reservoir at this level, releasing water in excess of power and irrigation demands along a 1,485' long spillway crest (Figures 33 and 34).[81] Sixty gate-controlled (ring seal gates) 8.5' outlet tubes, located in lines of 20 at elevations 934, 1034 and 1134, release additional excess flow, to a maximum possible level of 1,000,000 cfs. (Figures 35 and 36).

By 1939, drum gates, ring-seal gates, and central spillways were common dam auxiliary features. A potential 1,000,000 cfs of water falling 280 and generating 31,800,000 horse power (hp) — 19,300 hp per foot of gross spillway crest length — was "unprecedented" (Figure 37). A "curious" reader of *Engineering-News Record* noted:

> Relatively few dams have been built on large rivers with spillways on the main dam itself. . . . In such dams there has been preference for structures arched in plan so that the additional stability of wedding in the canyon would lessen any risk that might arise from vibration or from undermining of the downstream toe. . . . Certainly it will interest engineers to know just what the plans are for energy dissipation in or just below the Grand Coulee Dam.[82]

Like the Army Corps of Engineers at Bonneville Dam, the Bureau of Reclamation began a series of photo-elastic experiments on to-scale bakelite models of the spillway section, investigating stress conditions during hydrostatic pressure on the upstream dam face and foundation and on the downstream face and spillway bucket during maximum flood. (The 1:40 model of the downstream face of the spillway was equipped with a glass panel 6' long, allowing visual inspection of flow conditions in the spillway bucket. Jacob E. Warnock, Hydraulic Research Engineer, wrote "regardless of the amount of data which may be obtained by other devices, none has proved as effective as this in affording a mental image of the true behavior of the water.") This data and mental imagery, evaluated in the context of site topography, location of the tailrace, and riverbed characteristics, suggested a spillway bucket, curved in section (50' radius) and placed at a very low elevation (Figure 38). Despite the care taken in spillway design, the wasted energy at the toe

---

[81] "Annual Project History, Columbia Basin Project," Vol. VIII, 1940, pp. 156-161.

[82] Letters to the Editor, "Overpour Hazard at Grand Coulee at Grand Coulee Dam," *Engineering News-Record,* September 6, 1934, p. 308.

remained considerable; Bureau engineers anticipated a degree of erosion and scour and included the installation of a permanent spillway drydock and caisson in their project design.[83]

By 1943, after only two seasons of high-water passage over the spillway crest, the Bureau of Reclamation applied to the War Production Board for man-power and strategic materials sufficient to repair the "badly eroded" spillway and to construct the permanent maintenance facilities. "We believe," they argued, "that the cost of the repairs and the use of the required strategic materials is of small consequence as compared to the value of the electric energy now being delivered to vital war industries in the Northwest." The War Department agreed, and auxiliary outlets in the right powerhouse to bypass water during low-water season (thus avoiding all use of the spillway); a "submerging-type" caisson for unwatering 50' sections of the spillway bucket; and drydock facilities for erecting, storing, and maintaining the caisson equipment were constructed between 1942 and 1947.[84]

Model studies also suggested that both the tailrace slopes *and* the immediate downstream river bank be riprapped to an average depth of 5' in order to mitigate erosion, undercutting, and earth slide.[85] In 1937, Savage and members of the Bureau's board of consulting engineers expressed confidence that this riprap was "ample for any anticipated stream flow."[86] Within three years, however, continued undercutting of the unstable banks ("a source of almost continuous trouble and great expense from the earliest days of the work") had generated substantial slides, threatening to block the right tailrace area and disrupt power generation from the left powerhouse. In 1940, the Bureau contracted for excavation of an additional 1,000,000 cubic yards of overburden from the west tailrace slope and in 1942 and 1943 government forces revised portions of both the east and west tailrace slopes and replaced the riprap.[87]

---

[83] "Vancouver Meeting of [American Society] of Civil Engineers Centers on Columbia River," *Engineering News-Record*, July 19, 1934, p. 84; Jacob E. Warnock, Hydraulic Research Engineer, Bureau of Reclamation, "Experiments Aid in Design at Grand Coulee Dam," *Civil Engineering*, November, 1936, Folder: Columbia Basin, Dams & Reservoirs, Grand Coulee Dam, May 1935-December 1936, Box 535, Decimal Classification 301.1, Project Correspondence File 1930-1945, Columbia Basin Project, R.G. 115, NARA-RMR, p. 737.

[84] H.W. Bashore, Commissioner, Bureau of Reclamation, to Mr. J.A. Krug, Director Office of War Utilities, War Production Board, August 26, 1943, Folder: Columbia Basin, Engineering Reports, Siphons and Spillways, August 1943 through, Box 538, Decimal Classification 301.7, Project Correspondence Files, 1930-1945, Columbia Basin Project, RG 115, NARA-RMR.

[85] "Annual Project History, Columbia Basin Project," Vol. 3, 1936, pp. 38, 191-192.

[86] "Annual Project History, Columbia Basin Project," Vol. 5, 1937, p. 47.

[87] "Annual Project History, Columbia Basin Project," Vol. IX, 1941, p. 42.

PUMPING STATION

Both the pumping station and the power plant (see below) are auxiliary structures of Grand Coulee Dam, incidental to the dam's ability to hold the Columbia River and yet essential to the dam's function and use. The pumping station lifts water from Lake Roosevelt to the Grand Coulee and therefore marks the first stage of the water-distribution system that defines Grand Coulee as a reclamation dam (see Figures 9 and 10). Within the concrete pumping-station dam (tied to and constructed in-pace and in-kind with the main dam) are six 65,000 hp pumps and six 67,500 hp reversible pump/generators, each connected to one of 12 discharge pipes (Figure 39). Left powerhouse units L-1, L-2, and L-3 each supplies power to a pair of the pumps which can lift 1,600 cfs to the feeder canal located 280' above the dam site and 1/2 mile from the Grand Coulee (Banks Lake). The pump/generators can lift 2,000 cubic feet of water per second to the feeder canal. In 1981, the pumping units were modified to also serve as generators, powered by water from Banks Lake that is allowed to fall 280' back down the discharge pipes (used here as penstocks) whenever available water is in excess of irrigation needs and power demands are high.[88]

In 1951, princesses of the Washington State Apple Blossom Festival poured water collected from all 48 states into the main canal of the Columbia Basin project, initiating the first delivery to project lands. Completion of the entire system of canals, dams, reservoirs, lateral ditches, and ditches drawing water from Banks Lake for delivery to 500,000 acres (one-half the projected total) took over 20 years, at a greater cost than Grand Coulee Dam.[89]

POWER

Power production was a central component of the Grand Coulee Dam project, providing the means of pumping water from Lake Roosevelt to the Grand Coulee, providing power to project farmers and communities, and ideally allowing income generation sufficient for dam operation and maintenance and for the repayment to the United States for the cost of the dam and power plant and one-half the cost of the irrigation works. In an ironic conclusion to the power-market debate that had dominated the early years of project history, the United States' entrance into World War II dramatically escalated this heretofore-inadequate demand. Under contract modification, CBI installed four rather than two generators in the completed left powerhouse and through emergency appropriation rushed completion of the right powerhouse, where the penstocks had

---

[88] "Annual Project History, Columbia Basin Project," Vol. VI, 1938, p. 198.

[89] Pitzer, *Grand Coulee*, p. 364.

been installed and the foundation placed but final structural completion had waited development of a considerable portion of the irrigable area (Figure 40).[90]

Power facilities integrated within the dam had of course been placed during the course of construction (Figure 4). In June, 1938 Western Pipe & Steel Company began construction of 18 pipe-steel penstocks 290' long and 18' in diameter (nine per powerhouse). In addition, Western Pipe & Steel constructed the 12 "comparatively short," 14' inlet pipes associated with the pumping plant (see above) and three 290' 7' diameter penstocks, which fed the small left-powerhouse generators that would provide "station-service" power for the gates and valves and for Engineer Town.[91]

"The largest ever constructed," the 18' diameter units were too large for shipment to the dam site and were instead built in sections at Western Pipe & Steel's Electric City fabrication plant (3.5 miles from the dam, at the government railroad siding), using fusion-welding technology. Upon completion, the welds were examined by x-ray, hydrostatic tested, and the penstock section cleaned, washed, painted, and transported by truck and barge to the appropriate powerhouse.[92] Here each was hoisted to the octagonal holes left in the dam and field welded to adjoining sections (Figure 42). These field welds were checked with portable x-ray equipment and the entire penstock checked for line and grade. Seventy-two-inch ring-seal gates were installed at the lower ends of the penstocks, immediately ahead of the turbines and, finally, all annular spaces were backfilled with concrete.[93]

---

[90] In sharp contrast to the depression-era make-work effort, when men and materials were in abundant supply, war-time austerity measures affected right powerhouse construction. The Bureau reported that "this was particularly true of both structural and reinforcing steel, and metal pipe, as well as skilled labor. . . . One of the most important changes of this nature was the change in design of the right powerhouse roof. The original plans contemplated a structural steel purlin roof supported by steel trusses, as used in the left powerhouse. Structural steel was not available. However, by purchasing the contractor's salvaged steel girders formerly used in his construction trestle on the dam, a satisfactory support for the 'pan-type concrete slab and joints construction' was obtained" ("Annual Project History, Columbia Basin Project," Vol. 9, 1942, p. 134).

[91] USDI BOR, Memorandum for the Press, January 31, 1938, Folder: Columbia Basin, Correspondence re Construction and Operation of Penstock Tunnels, Box 538, Decimal Classification 301.61, Project Correspondence Files, 1930-1945, Columbia Basin Project, RG 115, NARA-RMR.

[92] "Annual Project History, Columbia Basin Project," Vol. VII, 1939, p. 226; USDI BOR, Memorandum for the Press, January 31, 1938, Folder: Columbia Basin, Correspondence re Construction and Operation of Penstock Tunnels, Box 538, Decimal Classification 301.61, Project Correspondence Files, 1930-1945, Columbia Basin Project, RG 115, NARA-RMR.

[93] "Annual Project History, Columbia Basin Project," Vol. VII, 1939, pp. 226, 229, 232-233; "Annual Project History, Columbia Basin Project," Vol. VIII, 1940, pp. 32, 69.

In the spring of 1940, Government forces began installation of the two 10,100 kw station-service units, using turbines manufactured by Pelton Water Wheel Co. and generators manufactured by Westinghouse Electric & Mfg Co. The Bureau announced that on March 22, 1940 the first power would be delivered from Grand Coulee Dam via a temporary tie line to the Bonneville transmission system: "After only 7.5 yrs of construction, with the dam yet a year from completion, the dam's power machinery, in the shape of two small 10,000 kilowatt units, began amortizing the investment of the United States."[94]

Substantial delivery of commercial power sufficient to meet the needs of war industries was not realized until October 4, 1941, following installation of a 150,000 hp hydraulic turbine, manufactured by Newport News Shipping and Drydock Co., a 108,000 kilowatt generator manufactured by Westinghouse (together composing unit L[eft]-3), and completion of a 115-kv switchyard and a 230-kv yard. Again, the nation celebrated:

> When Grand Coulee's first great hydroelectric generator starts developing power this Saturday, it will be a little over 8 year since half a dozen Bureau of Reclamation engineers braved an infrequent Eastern Washington rainstorm to drive a simple fir stake amidst the sagebrush of the Columbia River valley . . . Between September 9, 1933 and October 4, 1941 the Bureau of Reclamation, its contractors, 70,000 workers, and modern construction machinery have built a massive structure of 21,000,000 tons, created a huge reservoir 133 miles long, constructed a powerhouse about 18 stories high and two city blocks long, and put into operation a 108,000 kilowatt generator, a third larger than any of similar type built heretofore. . . . During 1942, The Grand Coulee Dam will contribute a major share of the power needed to manufacture one-fourth of the Nation's anticipated [aluminum] output of 600,000,000 pounds.[95]

Turbine/generator units L-1 and L-2 were placed in service early in 1942, followed by unit L-6 on August 9, 1943, unit L-5 on November 8, 1943, and unit L-4 on February 12, 1944. "In order to speed the development of generating capacity for war production," two 75,000 kw generators manufactured for Shasta Dam augmented this production; both the turbines and generators had been manufactured prior to the war and had been in storage at Hoover Dam, waiting completion of the Shasta powerhouse (Figure 43). With these six large units, two Shasta units, and the station-service units, Grand Coulee was able to generate 818,000 kw (Figure 44). Ironically, given the increased power demand generated by the war, wartime restrictions on material and labor prevented rapid completion of the remaining units: on October 27, 1942, the War

---

[94] "Annual Project History, Columbia Basin Project," Vol. VIII, 1940, p. 33; USDI BOR Press Release, October 1, 1941, Folder: Columbia Basin, Dams & Reservoirs, Grand Coulee Dam, January 1939-December 1941, Box 534, Decimal Classification 301.1, Project Correspondence File 1930-1945, Columbia Basin Project, R.G. 115, NARA-RMR.

[95] USDI BOR Press Release, October 1, 1941, Folder: Columbia Basin, Dams & Reservoirs, Grand Coulee Dam, January 1939-December 1941, Box 534, Decimal Classification 301.1, Project Correspondence File 1930-1945, Columbia Basin Project, R.G. 115, NARA-RMR.

Production Board cut the priority for generators L-7, L-8, and L-9 and suspended work on the right powerhouse.[96]

THIRD POWERPLANT[97]

All eighteen Left and Right powerhouse units were placed in service by 1952, with a maximum generating capacity of 243,000 kv; this maximum, however, was obtainable only when sufficient water was available in Lake Roosevelt. During periods of high water (coinciding with periods of high summer-time power demand) power head was "wasted" over the Grand Coulee spillway. By 1966, following two-decades of domestic and international (Canada) negotiations and political wrangling, the BOR secured Congressional appropriation and Canadian approval for construction of upstream storage dams that would assure a consistent water level at Lake Roosevelt and that would allow construction of a massive Third Powerplant, ultimately capable of generating 9.2 million kw, using 12 600,000 kw generators fed by 40'-diameter penstocks.[98] The 20-story Third Powerplant/forebay dam was located at the east abutment. Its construction (the largest contract ever awarded by the BOR) involved removal of the right powerplant switchyard and much of old Mason City; construction of a new cofferdam; completion of a massive new forebay dam stretching from the original dam along the east side of the river; and removal of 250' (blocks 92 and 93) of the original dam. To the undoubted satisfaction of those who had built blocks 92 and 93 (and of those living downstream), the existing concrete proved "amazingly hard and . . . took longer than anticipated to break up." A protective slot in the dam, excavated slowly by jack-hammer and minor charges prevented the detonations from transmitting to the main dam structure (Figures 45-48).

CONCLUSION

In 1934, the Bureau of Reclamation described the Grand Coulee west cofferdam as "the greatest, or at least the largest," ever built. The ambiguous, and often forgotten, distinction between these two superlatives defines the difficulty of assessing the technological importance of Grand Coulee Dam. For Bureau of Reclamation designing engineers, Grand Coulee Dam presented few technological challenges not already faced at Hoover Dam (most notably content and cooling of large volumes of concrete). The Grand Coulee foundation was of sufficient strength to support a dam of "any height" demanded by the power and irrigation programs and the

---

[96] "Annual Project History, Columbia Basin Project," Vol. XI, 1943, pp. 132-140; Pitzer, *Grand Coulee*, pp. 250-253.

[97] This is of necessity a grossly abbreviated discussion of Third Powerhouse political and construction history. See Pitzer, *Grand Coulee*, pp. 333-354 for a political history, and Bureau of Reclamation Third Powerplant Project Histories, 1969-1974 for a discussion of powerplant design and construction.

[98] Only six of these generators have been installed to-date.

economic largess of the federal government during the 1930s lessened the need for technological innovation and risk in response to economic concerns: a traditional massive concrete gravity dam rather than a less expensive multiple-arch structural dam was possible in the cost-benefit equation of the times. In contrast, within the parameters of conservative design, economic expedients were central to construction methods. The construction-plant innovations realized during removal of an unprecedented volume of overburden and placement of an unprecedented volume of concrete established Grand Coulee Dam "among the construction classics . . . [showing] that in planning field execution creative engineering reaches as great heights as in the activities of the designing engineer."[99] Although none of the major economic expedients at Grand Coulee (the ice dam, the west cofferdam, the conveyor belt system, the Westmix plant) were pioneering in concept, each, civil engineers of the time argued, was executed to a size and capacity "so far overshadowing earlier applications . . . as to represent radical innovations."[100] Each established a precedent, *redefining the engineering and construction community's understanding of what was possible*, within a given timeframe and a given budget.

Size and greatness are more easily correlated when evaluating the historical impact of the dam on the Pacific Northwest region: Construction of the largest thing on earth allowed employment of over 70,000 men and created a stream of manufacture goods, dollars, and jobs that reached 45 states. This immediate employment during an era of nearly universal unemployment provided the final catalyst to construction of a politically untenable and economically suspect project, thus placing Grand Coulee with the major public-works projects of the depression era, representative of a significant new public/private social and economic contract. The unprecedented volume of water stored behind Grand Coulee Dam allows irrigation and cultivation of over half-a-million acres of land, a substantial impact on the economic and social history of the region and effective symbol of the Bureau of Reclamation's mission to make the desert bloom. By March, 1944, this unprecedented water volume, run through generators of unprecedented size, established a world's record for electrical production by a single plant in a month's time with a gross output of more than 621,000 kilowatt hours; this unprecedented output powered Pacific Northwest aluminum plants and other war industries (an estimated total of $1.5 billion of regional industrial

[99] Editor, *Engineering News-Record*, "A Construction Classic," *Engineering News-Record*, August 1, 1935, p. 139.

[100] Editor, *Engineering News-Record*, "Earthmoving by Factory Process," *Engineering News-Record*, August 1, 1935, p. 139.

installations)[101] during World War II, allowing effective prosecution of the war effort, without disrupting the domestic power supply.[102]

[101] State of Washington, "Supplementary Report of the Columbia Basin Commission of the State of Washington, April 1, 1934-Jan 1. 1945," p. 9, Folder: Reports of the Columbia Basin Commission of the State of Washington, Box 530, Columbia Basin Project, Decimal Classification 301, Project Correspondence File, 1930-1945, RG 115, NARA-RMR.

[102] Pitzer, *Grand Coulee*, pp. 247-249. Pitzer argues that contemporary and current claims that Grand Coulee and Bonneville dams "won" the war" are dramatically overstated. The combined electrical output allowed aluminum manufacture *without* disrupting the domestic supply: "Grand Coulee allowed the government to produce the aluminum and run Hanford, while not disturbing the day-to-day lives of most Americans. The government could have diverted power from domestic use but Grand Coulee, among other projects, made this unnecessary" (p. 249).

ANNOTATED BIBLIOGRAPHY

■ Secondary Sources

Pitzer, Paul. *Grand Coulee. Harnessing a Dream*. Pullman, Washington: Washington State University Press, 1994.

Massive study of all phases of Columbia Basin Project construction and implementation, with focus on economic and legislative rather than construction history. Concludes with a valuable annotated bibliography. Pitzer conducted research in the James O'Sullivan papers, Gonzaga University, Spokane Washington; Columbia Basin Commission papers, Washington State Archives, Olympia, Washington; Warren Magnuson, Henry Jackson, and Willis Batcheller collections, University of Washington, Seattle; Frank Banks papers and Columbia Basin Project collection, Washington State University, Pullman; Bureau of Reclamation RG 115, NARA, Denver.

■ Technical Journal References to Grand Coulee Dam

(The following list is a compilation from a variety of sources. Not all articles were reviewed during the course of this study).

1920-1933

Waller, O. L. "Main Features of Columbia Basin Project." *Engineering News-Record*, March 4, 1920, v. 84, p. 456.

Blanchard, C. J. "Filming the Columbia Basin Project." *Reclamation Record*, July 1923, v. 14, pp. 236-238.

Mead, Elwood. "Report on Columbia Basin Irrigation Project." *Engineering News-Record*, Sept. 24, 1925, v. 95, pp. 502-503.

Adams, Fred A. "What is the "Scheme of Development Upon Which the Inland Empire is Based?" *Modern Irrigation*, October 1925, v. 1, pp. 15-16.

Mead, Elwood. "Columbia Basin Special Commission makes Report." *Reclamation Era*, Oct. 1925, v. 16, pp. 154-156.

"Columbia Basin Project to be Studied." *Reclamation Era*, Dec. 1926, v. 17, no. 12, p. 212.

Mead, Elwood. "Planning the Columbia Basin Development." *Reclamation Era*, July 1927, v. 18, pp. 98-102.

Tiffany, R. K. "World's largest irrigation project now being planned by four States of Northwest." *Modern Irrigation*, Sept. 1927, v. 3, pp. 16-17, 80.

Butler, John S. "Columbia River for Irrigation and Power." *Civil Engineering*, Sept. 1931, v. 1, pp. 1075-1080.

"Columbia Basin Project Report Shows Feasibility." *Reclamation Era*, March 1932, v. 23, pp. 52 and 54.

Schmitt, F. E., ed. "Columbia Basin Project Reported Feasible." *Engineering News-Record*, June 30, 1932, v. 108, pp. 907-911.

"Development Discussed by Engineers." *Engineering News-Record*, July 14, 1932, p. 20.

Robins, Col. Thos. M. "Improvements of the Columbia River (Grand Coulee Site." *Civil Engineering*, Sept. 1932, v. 2, no. 9, pp. 563-567.

Averill, Walter A., ed. "Preliminary work starts on Coulee Dam, portrait of Dr. Mead and tribute to him." *Pacific Builder and Engineer*, Sept. 2, 1933, v. 39, no. 35, p. 27.

"Grand Coulee — A Giant Power Threat; a description of the Columbia River project and its $63,000,000 first unit." *Baron's*, Dec. 25, 1933, v. 13, pp. 3, 8-9.

1934

Banks, F. A. "Columbia Basin Project." *Reclamation Era*, Jan. 1934, v. 25, no. 1, pp. 12-13.

"More Power for the Northwest; Grand Coulee Project." *Review of Reviews*, Jan. 1934, v. 89, pp. 48-49.

"8,000,000 kw. Goal of Columbia River Development; utilization of generating facilities from power, navigation, flood control and irrigation projects." *Electrical West*, Feb. 1934, v. 72, pp. 16-17.

"Grand Coulee; the Key to Columbia River Power." *Electrical West*, Feb. 1934, v. 72, pp. 18-19.

"8,000,000 kw. is Columbia River Goal; P.W.A. Projects at Grand Coulee and Bonneville." *Electrical West*, Mar. 17, 1934, v. 103, pp. 409-410.

Darwin, A. G. "Grand Coulee Dam and Power Plant Specifications." *Western Construction News*, April 1934, v. 9, pp. 103-114.

"Three Big Dam Operations Begin in the Northwest; Construction Operations at Bonneville, Grand Coulee, and Fort Peck." *Engineering News-Record*, April 5, 1934, v. 112, pp. 441-445 (Grand Coulee - pp. 442-444).

▸ The following five articles are from *Pacific Builder and Engineer*, April 14, 1934, v. 39, no. 15.

"Preliminary Data on Design and Construction Features of Coulee Dam," pp. 22-23.

"Engineers' Report on Design of Grand Coulee Dam," pp. 23 and 30.

Averill, Walter A. "Stripping of Overburden at Coulee Dam Six Weeks Ahead of Schedule, pp. 24-29.

Stevenson, I.E. "Slide on Schedule," p. 29.

O'Sullivan, James. "The Conference of Consultants on Grand Coulee Dam, at Denver, March 29, 30, 31."

O'Sullivan, James. "Two Suggested Methods for Diverting the Columbia River at Coulee Dam." *Pacific Builder and Engineer*, June 9, 1934, v. 40, no. 23, pp. 29-30.

"What's Doing at Grand Coulee Dam." *Pacific Builder and Engineer*, June 9, 1934, v. 40, no. 23, p. 35.

Bjork, B. E. "Bids Opened at Spokane for Grand Coulee Dam and Power Plant." *Western Construction News*, July 1934, v. 9, no. 7, pp. 224-229.

"Grand Coulee Project to Start." *Newsweek*, July 7, 1934, v. 4, pp. 6-7.

▸ The following three articles are from *Pacific Builder and Engineer*, July 7, 1934, v. 40, no. 27.

"Construction Starts Soon on Grand Coulee Dam," pp. 14, 16, 27.

"Inland Empire Celebrates Opening of Bids on Grand Coulee Project," pp. 16-17.

"Comparative Unit Bids on Grand Coulee Dam and Power Project," pp. 27-27.

Limerick, S. "White Power for the Northwest; Grand Coulee Project." *Review of Reviews*, Aug. 1934, v. 90, pp. 52-53.

"Developing the Columbia River Drainage Basin." *Civil Engineering*, Sept. 1934, v. 4, no. 9, pp. 443-459.

Banks, F. A. "Columbia Basin and Grand Coulee Projects." *Civil Engineering*, Sept. 1934, v. 4, no. 9, pp. 456-459.

Banks, F. A. "The Grand Coulee High Dam . . . And the Irrigation of the Columbia Basin." *Pacific Builder and Engineer*, Sept. 1, 1934, v. 40, no. 35, pp. 17-20.

Hockley, C. C. "Power Possibilities in Northwest." *Paper Trade Journal*, Sept. 20, 1934, v. 99, pp. 85-86.

"Progress Schedule and Construction Methods for Grand Coulee Dam." *Pacific Builder and Engineer*, Oct. 6, 1934, v. 40, no. 40, pp. 16-18.

"Preliminary Construction at Grand Coulee Dam Speeds Ahead." *Pacific Builder and Engineer*, Nov. 3, 1934, v. 40, no. 44, pp. 26-27.

"Power, Navigation and Irrigation in Two Projects on the Columbia." *Engineering News-Record*, Nov. 29, 1934, v. 113, pp. 678-685.

Savage, J. L. "Dam Stresses and Strains Studied by Slice Models." *Engineering News-Record*, Dec. 6, 1934, v. 113, no. 23, pp. 720-723.

1935

Magnusson, C. E. "Hydroelectric Power in Washington; a brief on proposed Grand Coulee dams." University of Washington, Engineering Experiment Station, Bulletin 78, 1935, pp. 1-29.

Banks, F. A. "Columbia Basin Project (address at meeting of National Reclamation Association." *Reclamation Era*, Jan. 1935, v. 25, no. 1, pp. 12-13.

"Work Starts on Cofferdams on Coulee Project." *Pacific Builder and Engineer*, Jan. 5, 1935, v. 41, no. 1, pp. 39-40.

"Grand Coulee High Dam, With Reclamation and Power Development Unqualifiedly Endorsed." *Pacific Builder and Engineer*, Jan. 5, 1935, v. 41, no. 1, p. 43.

Hitchcock, G. W. "The World's First All-Electric City." *Pacific Builder and Engineer*, Jan. 19, 1935, v. 41, no. 3, pp. 3-4.

"Details of Cofferdams, Columbia Basin Project." *Reclamation Era*, Feb. 1935, v. 25, p. 35.

"Wanted: Buyers for One Billion Kw-hour; Columbia River Development." *Electrical West*, Feb. 1935, v. 74, pp. 24-32.

Berkey, C. P. "Foundation Conditions for Grand Coulee and Bonneville Projects." *Civil Engineering*, Feb. 2, 1935, v. 5, no. 2. pp. 67-71.

"World's Largest Construction Conveyor Speeds Excavation at Grand Coulee." *Western Construction News*, Mar. 1935, v. 10, no. 3, pp. 80-82.

"Basis of Findings of Pacific Northwest Regional Planning Commission on the Grand Coulee Dam." *Pacific Builder and Engineer*, Mar. 2, 1935, v. 41, no. 9, pp. 28-29.

"M.W.A.K. Rush Grand Coulee Cofferdam." *Pacific Builder and Engineer*, Mar. 2, 1935, v. 41, no. 9, pp. 36-38.

Rorty, J. "Grand Coulee." *Nation*, Mar. 20, 1935, v. 140, pp. 329-331, 446-448 and v. 141, July 24, 1935, pp. 101-102.

Kirkpatrick, G. "On a Natural Damsite at Grand Coulee." *Scientific American*, Apr. 1935, v. 152, pp. 198-200.

Markhus, O. G. F. "Grand Coulee Contractors Build Mason City." *Reclamation Era*, Apr. 1935, v. 25, no. 4, pp. 69-72, 84.

"M.W.A.K. Completes First Cofferdam at Grand Coulee." *Pacific Builder and Engineer*, Apr. 6, 1935, v. 41, no. 14, pp. 33-34.

"Construction Work in Progress." *Engineering News-Record*, Apr. 18, 1935, p. 574.

"How Mason-Walsh-Atkinson-Kier Built World's Largest Cellular Cofferdam in 90 days — Establishing a New Record." *Pacific Builder and Engineer*, May 4, 1935, v. 41, no. 18, pp. 24-31.

Markhus, O. G. F. "The Belt Conveyor System at Grand Coulee." *Reclamation Era*, June 1935, v. 25, no. 6, pp. 109-112.

"Grand Coulee, illustrations." *Electrical West*, June 1935, v. 74, p. 71.

"Cofferdams 3,000 Feet Long Built at Grand Coulee." *Western Construction News*, June 1935, v. 10, no. 6, pp. 162-164.

"M.W.A.K. Purchases World's Largest Concrete Plant for Grand Coulee Dam." *Pacific Builder and Engineer*, June 8, 1935, v. 41, no. 23, pp. 26-27.

"Grand Coulee Revised Plans Omit Power." *Electrical West*, July 1935, v. 75, p. 54 (same, abridged, *Engineering News-Record*, June 13, 1935, v. 114, p. 861).

Carter, C. H. "Change of Plan for Grand Coulee Dam." *Reclamation Era*, July 1935, v. 25, no. 7. p. 135.

Walter, A. "High Dam at Grand Coulee Assured by Change Order." *Pacific Builder and Engineer*, July 6, 1935, v. 41, no. 27, pp. 30-32.

Case, Robert O. "Eighth Wonder of the World." *Saturday Evening Post*, July 13, v. 208, p. 23.

Brosky, A. F. "Elaborate Conveyor Systems Set Up at Grand Coulee Dam Diggings." *Steel*, July 22, 1935, v. 97. pp. 24-27.

▸ Grand Coulee Dam issue of *Engineering News-Record*, Aug. 1, 1935, v. 115, no. 5, (Progress at Grand Coulee) contains the following articles.

Editorial Introduction, pp. 139-140.

Keener, Kenneth G. "Grand Coulee Project and Dam," pp. 141-143.

"Ten Months' Construction Progress," pp. 144-147.

"Constructing the First Cofferdam," pp. 148-151.

Donaldson, Francis. "Belt Conveyors for Spoil Transportation: Planning for Excavation Disposal," pp. 152-153; "The Belt Conveyors in Operation," pp. 153-155.

Mercier, Stanley M. "Designing the Belt System," pp. 156-157.

"Making Aggregate at Grand Coulee," pp. 158-160.

Vivian, C. H. "Developing the Mighty Columbia." *Compressed Air Magazine*, Sept. 1935, v. 40, no. 9, pp. 4815-4821.

"Grand Coulee Excavating Program Modified to Meet Changed Designs." *Western Construction News*, Sept. 1935, v. 10, no. 9, p. 53.

"Slides in West Abutment Area Are Problem at Grand Coulee Dam." *Western Construction News*, Sept. 1935, v. 10, no. 9, pp. 258-259.

"Building the Construction Highway at Grand Coulee Dam." *Pacific Builder and Engineer*, Sept. 7, 1935, v. 41, no. 36, pp. 34-36.

Davenport, Walter. "Power in the Wilderness." *Colliers*, Sept. 21, 1935, v. 96, pp. 10-11.

▸ The following three articles are from *Compressed Air Magazine*, Oct. 1935, v. 40.

O'Connell, H. "Grand Coulee Dam," pp. 4840-4844.

"Construction Methods at the Grand Coulee Dam," pp. 4848-4855.

"Housing Grand Coulee Workers," pp. 4845-4847.

"Economic Aspects of Grand Coulee; studies in electric heating and building insulation at Mason City." *Electrical West*, Oct. 1935, v. 75, pp. 54-55.

"Moving a Mountain a Mile at Grand Coulee." *Pacific Builder and Engineer*, Oct. 12, 1935, v. 41, no. 41, pp. 28-38.

Markhus, O. G. F. "Diversion and Care of the River." *Reclamation Era*, Nov. 1935, v. 25, no. 11, pp. 217-219.

"Recent Views of Columbia River Projects; Grand Coulee Dam and Bonneville." *Electric Engineering*, Nov. 1935, v. 54, pp. 1272-1273.

"Preparing Millions of Yards of Aggregate for Grand Coulee Dam." *Western Construction News*, Nov. 1935, v. 10, no. 11, pp. 310-315.

"Earth Pressure Tilts Pier of Bridge." *Engineering News-Record*, Nov. 7, 1935, p. 646.

"Aggregate Transported Across Columbia by Long Suspension Belt." *Engineering News-Record*, Nov. 14, 1935, v. 115, pp. 674-675.

Holden, Ashley E. "America's Last Frontier." *Overland Trails*, Dec. 1935, v. 1, no. 1, pp. 15-16.

Jenks, Robert J. "Producing Aggregate for the World's Largest Concrete Structure." *Pacific Builder and Engineer*, Dec. 7, 1935, v. 41, no. 49, pp. 26-32.

"Feeder Grizzly on Conveyors." *Engineering News-Record*, Dec. 12, 1935, p. 821.

1936

Thompson, C. "Grand Coulee Dam Concreting Plant is Notable for Design Efficiency." *Western Construction News*, February, 1936.
Bins, batching equipment, and four 4-yd mixers arranged in compact tower structure on west abutment; capacity of 6000 cu yd per day; placing trestles and methods described.

Webb, C.E. "Columbia Basin Project." *Engineering Journal*, February, 1936.
General review of plans for project and progress in construction at Grand Coulee.

Mercier, S.M. and G.F. Dodge. "Grand Coulee Dam — World's Greatest Conveyorized Construction Plant." *Journal of the Boston Society of Civil Engineers*, April, 1936.
Symposium of 2 papers: Excavation and Conveyor System; Grand Coulee Aggregate Plant.

Markhus, O. G. F. "Aggregate Production for Grand Coulee Dam." *Reclamation Era*, June, 1936.
Excavation of dams and gravel; crushing plant; aggregate screening an (sic) washing; delivery of refined aggregates; handling bulk cement; delivery of concrete to forms.

"Details of Concreting Procedure at Grand Coulee Dam." *Western Construction News*, July 1936.
Operations involving placing 4,500,000 cu yd of concrete; data on foundation grouting, step-by-step review of concrete placing methods, form design, cooling system and contraction joint grouting; inspection.

"Program for Grand Coulee's Second Cofferdam." *Engineering News-Record,* October, 1936.
Outline of design contemplating construction of U-Section cribs to permit gradual closure with stoplogs; cribs of different design in upstream and downstream arms; unwatering of present river channel set for latter part of December.

Riddle, C.D. "Construction Plant at Grand Coulee Dam." *Civil Engineer,* October, 1936.
Large-scale operations for cofferdam, excavation and for aggregate productions; earth handling on huge scale; schemes to save time; screening plant; airplane tripper with 75-ft wing booms.

"Diverting Columbia at Grand Coulee with Timber Cribs and Gravel Fills." *Western Construction News,* December, 1936.
Description of 2 cross-river cofferdams constructed to permit unwatering & excavation in main channel area; crib bottoms designed from 40,000 soundings taken in river channel; main cribs are 64 x 90 ft; cofferdam construction.

Young, H.W. "Compressed Air at Grand Coulee Dam." *Compressed Air Magazine,* December, 1936.
Examples of utilization of compressed air in construction of dam.

Gordon, G. "Use of Refrigeration in Building Grand Coulee Dam." *Refrigerating Engineering,* January, 1937.
Use of ammonia brine refrigerating system for freezing arch dam 100 ft long 40 ft high & 20 ft thick to save removal of 30,000 cu yd of excavation; design of arch & refrigerating plant; method of installing freezing points; operation of system, etc.

McFarland, D. "Special Panel Form Staging." *Engineering News-Record,* April 8, 1937.
Details of staging for work on concrete forms which can be hung up against forms when not in use, employed in construction of Grand Coulee dam.

"New Record in Pouring Concrete." *Engineering News-Record,* July 15, 1937.
Recent progress at Grand Coulee Dam; completion of preliminary work and preparation for concrete placing schedule of 440,000 cu yd per mo; changes in handling materials.

"Grand Coulee Dam." *Oxy-Acetylene Tips,* August, 1937.
Construction problems, cofferdams, gravel plant and conveyors, application of oxyacetylene welding and welding in construction.

"Grand Coulee Cofferdam Removal." *Engineering News-Record,* September 2, 1937.
Methods used in demolition of cofferdam for construction of Grand Coulee Dam; excavation totals; steel sheeting pulled by cranes and timber cribs uprooted by power shovels.

"Grand Coulee High Dam: Design and Engineering Features, Cost Data, etc." *Engineering News-Record,* December 23, 1937, 119:1021-4.

Outline of plans for completion of dam in Eastern Washington to its ultimate height of 550 ft & length of 4500 ft, requiring nearly 6,000,000 cu yd of concrete in addition to 4,500,000 cu yd already in place; finances, etc.

"Grand Coulee Dam." *Engineer,* February 4, 1938.

Skerrett, R.G. and L. Gain. "Le Barrage de Grand-Coulee sur le Fleuve Columbia." *Technique des Travaux,* April, 1938.
Report on design and construction of Grand-Coulee dam.

Caufourier, P. "Le Barrage de Grand Coulee sur le Columbia." *Genie Civil,* May 14, 1938.
Compilation of design and construction of Grand Coulee dam.

"Work Resumed at Grand Coulee With Reconditioning of Plant." *Western Construction News,* July, 1938.
Progress report on construction of dam; rehabilitation of aggregate production system, dismantling of old concrete, placing trestles, moving mixing plants and improving camp; concrete placing cranes; penstock fabrication.

"Facts and Figures on Grand Coulee." *Power,* October, 1938, 82:550-2.
Survey of dam site and surrounding terrain, including geology and water resources; review of projected dam, hydroelectric power plant, and pumping plant.

Merrill, A.A. and J.P. Murphy. "Some Engineering Features in Construction of Grand Coulee Dam." General Electric Review, November, 1938.
Outline of Columbia River Basin reclamation project; possibilities relative to irrigation and power production; river diversion; removal of overburden; mixing and placing of concrete.

"Steel Gates Close Gaps in Dam." *Engineering News-Record,* December 8, 1938.
Use of 70-ton gates moved along dam crest to effect closure of gaps left temporarily in spillway section of Grand Coulee Dam.

Brabrook, R.S. "Erecting 3600-Ft Steel Trestle for Placing Grand Coulee Concrete." *Western Construction News,* February, 1939.
Construction of structural steel trestle, nearly 3600 ft long and 200 ft high, for placing 45,500,000 cu yd of concrete to complete Grand Coulee dam, being built by Bureau of Reclamation on Columbia River; erection procedure.

"Concrete Placing at Grand Coulee — from Gravel Pit to Forms." *Western Construction News,* June, 1939.
Progress report on construction of dam; concrete placing going forward at rate of about 12,000 cu yd every 24 hr; typical mass concrete mixes showing changes in proportioning to meet variation in production of aggregates; mixing plants, etc.

"Handy A-Frames for Form Panels." *Engineering News-Record,* September 14, 1939.

Description of A-frames for raising 25-ft for panels on Grand Coulee Dam made up with 2-in. pipe welded up on job.

Hutton, S.E. "Grand Coulee Dam and Columbia Basin Reclamation." *Mechanical Engineering,* September, 1940.
Peculiarities of Columbia River; geological, geographical, climatic, and economic features of western third of United States; energy available at Grand Coulee dam; power houses, turbines, penstocks, and coaster gates, generators and transformers, etc.

Burnard, J.J. "Turbines for Grand Coulee Dam." *Advance Paper for the American Society of Mechanical Engineers,* September 3, 1940.
Grand Coulee power plant, when fully equipped will contain 18 15,000-hp main generating units and three 14,000-hp station service units, or total capacity of 2,742,000 hp; turbines are of vertical shaft single runner Francis type.

Danford, H.G. & F.W. Johnson. "Dam the Accidents!" *Safety Engineering,* November, 1940.
Methods and equipment used in preventing accidents on Grand Coulee Dam; safety rules and regulations.

Grand Coulee Plant, Columbia River U.S. Bureau of Reclamation. "Grand Coulee Power 10 Years Off: Companies do not Oppose it, but do ask for Fair Compensation." *Public Service Magazine,* November, 1933, 55:137.

Stanley, D. "Grand Coulee — A Giant Power Threat: A Description of the Columbia River Project and its $63,000,000. First Unit." *Barron's,* December 25, 1933, 13:3, 8-9.

"Grand Coulee — Key to Columbia River Power." *Electrical West,* February, 1934, 72:18-19.
Costing some $375,000,000, this project will produce practically double amount of firm power available at Hoover Dam and will provide facilities for irrigating 1,200,000 acres of land; notes on dam; power house; irrigation; cost of power.

Darwin, A.G. "Grand Coulee Dam and Power Plant Specifications." *Western Construction News,* April, 1934.
U.S. Bureau of Reclamation project comprising low-head development of 1,575,000 kw. ultimate capacity & irrigation for area of 1,200,000 acres in central Washington; geology of Grand Coulee damsite on Columbia River; foundation grouting & drainage, etc.

"Sureity Companies invest in Grand Coulee Project." *Eastern Underwriter,* June 29, 1934, 35:28+.

"Grand Coulee Dam, Washington." *Engineering News-Record,* October 11, 1934.
Summary of unit prices bid on construction of dam in Washington, which is of concrete gravity section, 300 ft. in maximum height, with overflow section 1800 ft. long, and two non-overflow power-house sections 592 and 754 ft. long.

"Grand Coulee Dam and Power Plant." *Specifications of the U.S. Bureau of Reclamation, No. 570,* December 31, 1934.
Schedule, specifications and drawings for construction of concrete-gravity dam on Columbia River, in Washington, about 300 ft. long, 300 ft., max. height, ultimate height 500 ft., including permanent cofferdam below main dam.

Magnusson, C.E. "Hydroelectric Power in Washington: A Brief on Proposed Grand Coulee Dams." *University of Washington Engineering Experiment Station Bulletin,* January, 1935, 78:1-29.

Magnusson, C.E. "Hydroelectric Power in Washington." *University of Washington Engineering Experiment Station Bulletin,* February 1935.
Engineering data of general interest on several proposed Grand Coulee dams; reservoir sites; potential water storage in Columbia River above Grand Coulee dam site; estimated cost data; irrigation by pumping; high dam vs. low dam.

"Cofferdam 3,000 Ft. Long Built at Grand Coulee." *Western Construction News,* June, 1935.
Method of construction of sheet-pile cofferdam of cellular type; 7053 piles, involving more than 12,500 tons of steel and total length of about 791,000 ft were driven in 3 months; description of gravel and concrete plants.

Keener, K.B. et al. "Progress at Grand Coulee." *Engineering News-Record,* August, 1935.
Symposium on design and construction of Grand Coulee dam having proposed ultimate height of 540 ft., 1650 ft long;, etc.

"Concrete Dispatching System." *Engineering News-Record,* September 10, 1935.
Description of electric signal boards to transmit orders, automatic control for aggregate combinations and comprehensive system for checking form blocks; concrete placing operations in west cofferdam; routing and placing of concrete.

"Preparing Millions of Yards of Aggregate for Grand Coulee Dam." *Western Construction News,* November, 1935.
Equipment an layout of gravel plant designed to meet rigid specifications for mass concrete.

"Concrete Mixing and Placing at Grand Coulee Dam." *Engineering News-Record,* January 23, 1936.
Description of first of 2 duplicate mixing plants, each with capacity of 320 cu yd per hr, having floor area of only 42 sq ft, but total height exceeding 250 ft; batcher floor and automatic-control equipment.

■ **Bureau of Reclamation, Army Corps of Engineers, United States Geological Survey, State of Washington and Congressional studies of the Columbia Basin Watershed, prior to 1933.**

Ex. Document No. 186 - 47th Congress, First Session. Report of and examination of Upper Columbia River and the Territory in its Vicinity in September and October, 1881, by Lieut. Thomas W. Symons, Corps of Engineers, U.S. Army, Chief Engineer, Department of Columbia.

Ex. Document No. 39 - 52nd Congress, Second Session. Letter from Acting Secretary of War, transmitting report by Captain Thomas W. Symons on Possibility of Navigation on Upper Columbia River, dated October 12, 1892.

Ex. Document No. 1112 - 63rd Congress, Second Session. Letter from the Secretary of War, transmitting report by the Board of Engineers for Rivers and Harbors, dated May 14, 1914.

Ex. Document No. 308 - 69th Congress, First Session. Letter from the Secretary of War, transmitting report by Chief of Engineers, U.S. Army, and Executive Secretary, Federal Power Commission, showing all navigable streams upon which power development appears to be feasible and the estimated cost of examination of same, submitted in accordance with the requirements of Section 3 of the Rivers and Harbors Act of March 3, 1925, dated April 7, 1926.

Federal Power Commission: Report on the Uses of the Upper Columbia River, by Board of Engineers: J.B. Cavanaugh, Colonel, Corps of Engineers, U.S. Army; D.C. Henny, Consulting Engineer, U.S. Reclamation Service; F.F. Henshaw, District Engineer, U.S. Geological Survey; C.S. Heidel, State Engineer, Montana; W.G. Swendwen, Commissioner, Department of Reclamation, Idaho; and Marvin Chase, Supervisor of Hydraulics, State of Washington. Issued 1923.

Senate Committee Print - 69th Congress, Second Session. Columbia Basin Project - Report of Special Commission, August 25, 1925; Board of Engineers' Report, February 1925; Board of Engineers' Report, April 6, 1924; Gault Report, March 1924. Printed, 1927.

Department of the Interior - Columbia Basin Project - Soil and Economic Conditions, by B.E. Hayden, Economist, Bureau of Reclamation, and Professor George Severence, State College of Washington. Issued 1928.

House Document No. 103, 73rd Congress, First Session. Columbia River and Minor Tributaries - A general plan for the improvement of the Columbia River and minor tributaries for the purpose of navigation and efficient development of water power, the control of floods, and the needs of irrigation. Two volumes, March 29, 1932.

Report on Columbia Basin Project, by Chief Engineer, U.S. Bureau of Reclamation. January 7, 1932. (Printed in Volume I, Document no. 103 - 73rd Congress, First Session, and in Hearings on H.R. 7446, - 72nd Congress, First Session).

■ **Reports of Hearings before Committees on Irrigation and Reclamation in the Senate and House of Representatives**

S-3808 - 67th Congress, Fourth Session. Bill authorizing the Secretary of the Interior to investigate and report to Congress upon the Columbia Basin Irrigation Project. December 6,7, and 13, 1922.

S-2663 - 69th Congress, First Session. Bill authorizing the Secretary of the Interior to cooperate with the states of Idaho, Montana, Oregon and Washington in allocation of the water of the Columbia River and its tributaries and for other purposes, and authorizing an appropriation therefor. February 2, 1926.

S-1462 - 70th Congress, First Session. Bill for the adoption of the Columbia Basin Reclamation Project and for other purposes. January 11 and 13, 1928.

H.R. 7029 - 70th Congress, First Session. Bill for the adoption of the Columbia Basin Reclamation Project, and for other purposes. January 16 and 17, 1928. Report No. 872 by Congressman Samuel B. Hill of Washington, dated March 10, 1928, to accompany H.R. 7029.

H.R. 7446 - 72nd Congress, First Session. Bill to provide for the construction, operation, and maintenance of the Columbia Basin Project in Washington, and for other purposes. May 25, 27, June 1, 2, 3 and 13, 1932.

S-2860 - 72nd Congress, First Session. Bill to provide for the construction, operation, and maintenance of the Columbia Basin Project in Washington, and for other purposes. June 21, 1932.

- **U.S. Department of Agriculture - Bureau of Chemistry and Soils**

Soil Survey of the Quincy Area, Washington, by A.W. Mangum and C. Van Duyne of the Department of Agriculture; and C.L. Westover of the Washington Geological Survey. Issued February 8, 1913.

Soil Survey of Franklin County, Washington, by Cornelius Van Duyne and J.H. Agee of the Department of Agriculture; and Fred W. Ashton of the Washington Geological Survey. Issued January 13, 1917.

Soil Survey (Reconnaissance) of Columbia Basin Area, Washington, by A.T. Strahorn, E.J. Carpenter, W.W. Weir, Scott Ewing, and H.H. Skrusekopf of the Department of Agriculture; and A.F. Heck and H.A. Lunt, State College of Washington. No. 28, Series 1929.

- **Reports by the State of Washington**

The Columbia Basin Irrigation Project, by Columbia Basin Survey Commission, Arthur J. Turner, Chief Engineer; J.C. Ralston, Consulting Engineer. Issued, 1920.

Columbia River Pumping, Power Project, by Willis T. Batcheller, Consulting Engineer, Seattle. Dated February 10, 1922. Not printed. (417 typewritten pages).

Columbia Basin Project, by George W. Goethals and Company, Inc.; Dated April 7, 1922.

- **National Archives and Records Administration, Rocky Mountain Region**

Bureau of Reclamation Record Group 115.

This record group is organized by projects and includes annual project histories; project reports; and correspondence files. The annual project histories include timelines, a list of important visitors, a synopsis of the Board of Consulting Engineers' reports; and a general discussion of the most important construction activities during the year, with statistics and graphic aids. See below for a general discussion of Columbia Basin Project annual histories, 1933-1945.

The Project Reports focus on "special features" of the project. They range in detail from, for example, an overview of the "Columbia Basin Project" to an "Analytical study of stress in pier gate of feeder canal, Grand Coulee." Assorted project reports re: the ice dam; cofferdam construction; and cement investigations were reviewed for this study. "Gault Report"; "Special features of Design and Construction"; "Report of Conferences with Banks"; "Analysis of Arch Dam at Grand Coulee;" and "Columbia River Pumping and Power Project," were also reviewed.

The voluminous correspondence files are organized by topic, and therein by year. Columbia Basin Project topics (decimal classifications) reviewed during the course of this study include: General Correspondence; Reports on Construction Features; Engineering, General; Dams & Reservoirs: Grand Coulee Dam; Publicity; Board and Engineering Reports on Construction Features; Correspondence re Construction of Coffer-dams; Correspondence re Construction and Operation of Penstock Tunnels.

■ **Bureau of Reclamation Grand Coulee Project Office, Grand Coulee, Washington**

In 1933, the Bureau of Reclamation established a Columbia Basin Project Photography Department "for the purpose of photographing work in progress and to perform miscellaneous photographic work necessary for publicity and court requirements." By 1938, three full-time photographers were employed on the project. The resulting 300,000+ black-and-white and color-slide images are on file at the NARA, Denver. The BOR project office also maintains a more manageable collection, composed of approximately 2,000 historic images (ca.1900-1945) reproduced from the NARA collection, and an additional 70,000 images post-dating dam construction (with focus on construction of the Third Powerplant).

All annual histories and special-feature reports are also maintained at the project office.

■ **Bureau of Reclamation Annual Columbia Basin Project Histories, on file at the National Archives and Records Administration, Rocky Mountain Region and at the Columbia Basin Project Office, Coulee Dam, Washington**

▸ All annotations are quoted from Chapter I of the project histories.

Volume I (1933) covers a summary of essential events leading up to establishment of the project, including a review of all reports of engineering and economic investigations; and historical reference to the Columbia River and its geographical description; a brief reference to early agriculture in the Big Bend area, and concludes with operations ending with the year 1933.

Volume II (1934) covers continued investigations of the project; preparation of specifications and plans for the "low" dam and power plant and awarding of the contract for its construction; surveys and contracts for construction of highway and railroad, the Government Camp (Coulee Dam) and other facilities, and operations by the general contractor. It also includes a brief summary of principal events prior to the establishment of the project, and the listing of reports of investigations in a chronological order.

Volume III (1935) includes reference to the Order for Changes issued by Secretary Ickes in June 1935, where the concrete to be placed under the contract for the "low" dam was ordered placed as the base, or foundation, of the ultimate high dam; the action of Congress approving the project; the completion of the United States construction railroad and the Columbia River highway bridge; the building of additional residences and other housing facilities in Government Camp; the establishment of executive headquarters at Coulee Dam; the beginning of economic surveys in the irrigable area and a review of precise geodetic surveys. Also covered, is construction by the contractor, including the west cofferdam, excavation of overburden, uncovering bedrock in the west area; opening of the gravel pit, processing of aggregate, and constructing plant for manufacturing and placing concrete; ceremony of pouring the first concrete, and expansion of the general construction plant.

Volume IV and V (1936, 1937) covers progress by the contractor, the Mason-Walsh-Atkinson-Kier Company, who placed 1,860.832 cubic yards of concrete in the dam, mostly from the west abutment to block 40; the removal of the west cofferdam and construction of the two cross-river cofferdams, and erection of the east mixing plant; excavation of 1,787,575 cubic yards of common and rock in east and center sections and the placing of 170,032 cubic feet of grout in 787 holes in bedrock; surveys relating to relocation of highways and railroads in reservoir areas; geological investigation; and the drilling of 36-inch Calyx holes.

Volume VI (1938) describe the completion of the MWAK contract; the awarding of the new contract for completion of the dam, left power house, and foundation for the pumping plant (Specification No. 757); the alteration and repair of construction plant equipment; initial placement of concrete using new construction plant.

VII (1939) describes Consolidated Builders Inc. and Western Pipe and Steel contracts but also the activities of several contractors engaged on the migratory fish control features. The WPA clearing project activities, and initial work on highway relocation are also covered in this volume.

Volume VIII (1940) describes Consolidated Builders, Inc., Western Pipe and Steel Company, and by various contractors engaged in constructing the migratory fish control features. Also included in this volume are further activities in the reservoir area in connection with the WPA clearing project, highway and railroad relocation, bridge construction, and river channel improvements at the Little Dalles.

Volume IX (1941) describes completion, to contract height, of the spillway training walls, final cooling of concrete, construction of the spillway piers and bridges; installation of drum gates and other mechanical and electrical features; excavation and removal of overburden in the left (west) tailrace area; placing of riprap on the west tailrace slide area; and miscellaneous work at the left powerhouse. Volume also covers relocation of county and state highways and the Great Northern Railway in the reservoir area, and river channel improvements at the Little Dalles. Also included in this volume are the WPA clearing project in the reservoir, the construction of migratory and game fish control facilities, and the installation of generating units and switching features at Grand Coulee Dam."

Volume X (1942) describes completion of the Consolidated Builders, Inc. contract, including the right powerhouse and transformer deck. The installation of two main generating units, and the completion of four additional power-transmission lines by the Bonneville Power Administration.

Volume XI (1943) describes installation of the fourth and fifth main generating units and two temporary Shasta units.

Volume XII (1944) describes a year of light construction in 1944, but one of maximum power output for war industries. The sixth main generating unit was placed in operation early in 1944 and all six main units plus two temporary units operating at nearly full capacity throughout the year.

Volume XIII (1945) describes another year of light construction. Maximum generation of power for war industries was continued until after the cessation of WWII in August. After this date, the demand for power decreased because of the shutdown of some war industries and the conversion of others from wartime to peace-time operations.

COLUMBIA BASIN PROJECT TIMELINE

Before 1902	U.S. Geological Service completes general reconnaissance of areas, elevations, artesian water supply, etc.
1896	Northern Pacific Railway Company completes preliminary engineering investigations of the Priest Rapids area.
1902 to 1916	U.S. Reclamation Service completes numerous surveys, reconnaissance and investigations for a water supply for various sections, including Palouse, Pasco, Priest Rapids, and Quincy areas.
1920	State of Washington finances engineering report and cost estimates by the Columbia Basin Survey Commission on an area of 1,753,000 acres to be irrigated by water diverted from Pend Oreille River and carried by a gravity canal 130 miles in length
1921	Review by Board of Engineers, U.S. Reclamation Service, of plan proposed by Columbia Basin Survey Commission.
1922	State of Washington finances report by Engineer Willis T. Batcheller on power and pumping plans (at Grand Coulee) for areas ranging from 1,403,000 acres to 1,857,000 acres.
1922	State of Washington finances review by George W. Goethals & Company, Inc., of plans and cost estimates on gravity plan proposed by Columbia Basin Survey Commission and pumping plan by Engineer Willis T. Batcheller.
1922	Federal Power Commission completes report on coordinating the efficient use of Columbia River water for irrigation and power purposes.
1924	U.S. Reclamation Service finances report on investigations by Engineer Homer J. Gault for irrigation of from 998,894 acres to 1,424,555 acres, considering both gravity and pumping plans.
1924	Board of Engineers, U.S. Reclamation Service, completes review of the Gault Report.
1925	USDI finances review of previous reports and an independent engineering and economic investigation by Boards of Engineers appointed by Special Columbia Basin Commission, covering areas from 1,054,000 acres to 1,893,000 acres.
1925	Completion of report by the Special Columbia Basin Commission on the Gault investigation and the reports of the two boards of engineers.

COLUMBIA BASIN PROJECT TIMELINE

1927	B.E. Hayden, reclamation economist, cooperating with Professor George Severance of the State College of Washington, completes economic investigation of Columbia Basin project.
1931	Release of Army Corps of Engineers' comprehensive report of investigations covering a period of three years' work on the use of upper Columbia River for navigation, flood control, power and irrigation purposes.
1932	Chief Engineer Bureau of Reclamation reports on plan for irrigating about 1,200,000 acres in Columbia Basin by means of pumping from Columbia River at Grand Coulee.
March 3, 1933	Columbia Basin Commission is created by act of state legislature.
April 26, 1933	Elwood Mead advises President Roosevelt that a low dam could be constructed at Grand Coulee for $60,000,000 as a first-stage unit of the ultimate Columbia Basin Project.
July 16, 1933	Dedication ceremony marking the beginning of construction at Grand Coulee.
July 27, 1933	PWA includes the Grand Coulee Dam project in the program contemplated under Section 202 of the National Industrial Recovery Act and allocates $63,000,0000 for the project.
September 16, 1933	Initial development of test pits and trenches.
December 1933	Goodfellow Brothers, of Wenatchee, Washington, subcontractor to David H. Ryan, initiates excavation at the dam site.
October 1934	Mason-Walsh-Atkinson-Kier Company (MWAK) commence active work at the dam site.
December 6, 1935	First concrete is poured in the Grand Coulee Dam.
April 17, 1936	Major slide begins in east forebay section.
August 24, 1936	Freezing operations begin at ice dam, at the toe of the east forebay slide.
March 17, 1937	Major leak develops in cell "G" of west cofferdam with inflow reaching 35 second feet. Flow is reduced to less than two second feet by April 30.
April, 1937	Ice Dam no longer needed and dismantlement begins.

COLUMBIA BASIN PROJECT TIMELINE

May 1, 1937	Excavation of common overburden is completed and last yard transported on the conveyor system.
October, 1937	Final cleanup of bedrock in foundation area is completed
October, 1937	East Powerhouse substructure is completed.
February 7, 1938	Consolidated Builders, Inc. (CBI) is awarded the contract for Specification No. 757, covering completion of Grand Coulee dam, the left powerhouse, and pumping plant foundation, for low bid amount of $34,442,240.
March 21, 1938	The MWAK contract (foundation of high dam and power plants), is completed one year and 12 days ahead of schedule. Upon completion of contract, foundation excavation and river diversion were complete, concrete had been poured to a maximum elevation of 1010 in the abutment sections (just beneath the el.1024 construction trestle) and to elevation 945 in the spillway section with the exception of blocks 39 and 40 which were carried to elevation 1000. The power house foundations were completed to elevation 948.8 and the training wall to elevation 980.
June, 1938	Western Pipe & Steel Company begins construction of penstocks, at fabrication plant erected at Electric City (under Specifications No. 760).
1939	The Bureau of Reclamation reports that "in the construction annals of Grand Coulee Dam, the year 1939 will be outstanding because of the record-breaking concrete placing program. . . [and because] the control of the river at flood stage was successfully carried out by means of the spillway diversion channels."
April 22, 1939	Excavation is completed for pumping plant discharge tunnels.
May 25, 1939	CBI makes world-record concrete pour of 20,684.5 cubic yards in a continuous 24-hour run.
June, 1939	Excavation is completed at pumping-plant foundation.
September 20, 1939	For the first time, the entire flow of the Columbia River is diverted through the el. 934 outlet works.
October 6, 1939	First concrete pour in pumping plant foundation.
March 12, 1940	Installation of the 18' diameter steel penstock pipe is completed for the right powerhouse penstocks and the 12 14' inlet pipes in the pumping plant.

COLUMBIA BASIN PROJECT TIMELINE

May 31, 1940	Installation of the 18' diameter steel penstock pipe completed for the left powerhouse penstocks.
August 2, 1940	A number of blocks in the right abutment section of the dam are completed to their ultimate height at elevation 1311.06. The first cars drive along this completed portion of the roadway.
August 31, 1940	Installation of the two 12,500 kv-a station service generators is begun at left powerhouse.
September 30, 1940	Mining of raw aggregate at Brett pit is completed.
October 10, 1940	Installation is begun on spillway drum gates.
October 31, 1940	Atmospheric cooling tower is placed in operation to expedite concrete cooling.
October 31, 1940	Contractor's mess hall at Mason City closes after six years of service.
December 10, 1940	Bureau crews begin installation of the 150,000 hp. turbine at unit L-2 of the left powerhouse.
1941	At close of 1940, approximately 98% of the required concrete is in place, with 35,000 cu. yds remaining to be poured. Tasks for 1941 include concrete placing for the spillway bridge, elevator towers, sidewalks and parapets, and gate-guide extensions for the outlet works; installation of spillway drum gates; removal of the overburden in the left tailrace slide area; and miscellaneous work at the left powerhouse.
March 22, 1941	The two 12,500 kv-a station service units are placed in operation on the Bonneville transmission system. Celebration held for event.
April, 1941	All concrete cooling and contraction joint grouting complete, except at twist adjustment slots.
July 15, 1941	F. A. Banks, construction engineer for the Bureau of Reclamation, and Carl M. Smith, State Director of the Works Progress Administration, fell the last tree in the Columbia River Reservoir area.
April 26, 1941	Excavation at the west tailrace slide area is completed.

COLUMBIA BASIN PROJECT TIMELINE

October 4, 1941	The first 108,000 kv-a generator (Unit L-3) is placed in operation on the Bonneville transmission system after a 6-day test period. The event is broadcast over the C.B.S. radio network.
October 14, 1941	Concrete placement of spillway bridge is completed, essentially marking completion of the dam.
October 16, 1941	Extra Work Order no. 42, providing for construction of the right powerhouse transformer deck, is issued to Consolidated Builders, Inc.
October 23, 1941	Consolidated Builders, Inc. begins dismantling the construction trestle on the downstream face of the dam.
December 12, 1941	Last concrete is placed under Specification No. 757.
December 29, 1941	Extra Work Order No. 44 (Right powerhouse construction) is issued to Consolidated Builders, Inc., as a wartime emergency construction project.
January 1, 1942	Consolidated Builders, Inc. turns completed Grand Coulee Dam turned over to the Bureau of Reclamation for operation and maintenance.

Appendix

Abbreviated Descriptions for Structures of the Columbia Basin Project

ABBREVIATED DESCRIPTIONS FOR STRUCTURES OF THE COLUMBIA BASIN PROJECT[100]

Grand Coulee Dam is the key structure of the Columbia Basin Project, a multipurpose development utilizing waters of the Columbia River for power generation and irrigation. Irrigation works extend southward across the Columbia Plateau for 125 miles to the vicinity of Pasco, Washington, at the confluence of the Columbia and Snake rivers. In addition to the dam, principal project features include Franklin D. Roosevelt Lake; the Power Plant; the Pumping Station; Banks Lake and the feeder canal; North Dam; Dry Falls Dam; the Main Canal (including Pinto Dam and Billy Clapp Lake), West Canal, East Low Canal, and Potholes canals; O'Sullivan Dam; and Potholes Reservoir. In 1981, fifty years after initiation of work on Grand Coulee Dam, there were 333 miles of main canals, 1,993 miles of laterals, and 3,163 miles of drains and wasteways.

GRAND COULEE DAM AND THIRD POWERPLANT

Grand Coulee Dam is 5,223' long, 550' high, and (with the Third Powerplant) contains 11,975,000 cubic yards of concrete. The original dam was modified for the Third Powerplant by construction of a 1,170-foot-long, 201-foot-high forebay dam along the right abutment approximately parallel to the river. The spillway of the dam is controlled by 11 drum gates, each 135 feet long, and is capable of spilling 1,000,000 cubic feet of water per second. The dam also contains forty 102" diameter outlet tubes. Within the dam are 8.5 miles of inspection galleries and 2.5 miles of shafts.

FRANKLIN D. ROOSEVELT LAKE

The reservoir behind Grand Coulee Dam extends 151 miles northeast to the Canadian border and up the Spokane River, a tributary of the Columbia, to within 37 miles of Spokane, Washington. The total storage capacity of the reservoir is 9,652,000 acre-feet; of this capacity, 5,184,400 acre feet can be used to generate electricity.

---

[100] All data taken from USDI Bureau of Reclamation, "Columbia Basin Project, *Project Data Book* (Denver, Colorado: Government Printing Office, 1981), pp. 375-394.

POWER PLANT COMPLEX

Power facilities at Grand Coulee Dam consist of a powerplant on both the left and right sides of the spillway on the downstream face of the dam, the Third Powerplant on the downstream face of the forebay dam, an 11.95/115-kilovolt switchyard, a 230-kilovolt consolidated switchyard, and the 500 kilovolt Third Powerplant cable spreading yard and switchyard located west of Grand Coulee Dam.

As constructed, the left and right powerplants contained a total of eighteen 108,000-kilowatt units, nine in each powerplant. Rewinding these units has increased the capacity to 125,000 kilowatts each. Three small station service units of 10,000 kilowatts each in the left powerplant increase the total to 2,280,000 kilowatts for the left and right powerplants.

The Third Powerplant has six units. The first three units are rated at 600,000 kilowatts each and the last three are rated at 700,000 kilowatts each, for a total of 3,900,000 kilowatts.

As modified in 1981, six of the 12 units within the pumping station (see below) are capable of either pumping water or generating power. In the generating mode, each of these units has a capacity of 50,000 kilowatts for at total of 300,000 kilowatts.

Prior to construction of the Third Powerplant and of a central 230-kilovolt, low-profile, consolidated switchyard, switchyards were located on each side of the river, with the right switchyard in the area now occupied by the forebay dam. From the new consolidated switchyard, power generated in excess of station requirements is delivered to the lines of the Bonneville Power Administration (BPA), a marketing agency for federally produced power in the Pacific Northwest.

PUMPING STATION

The pumping station lifts water 292' to 300' (depending on the level of the reservoir) from Lake Roosevelt to Banks Lake, via a 1.6 mile feeder canal (see below). Designed to accommodate 12 pumping units, only six were installed at the time of construction; each of these six units can lift 1,600 cubic feet of water per second. Between 1965 and 1981, an additional six pumping/generating units were installed, each of which can lift 1,700 cubic feet of water per second or, when reversed, produce 50,000 kilowatts of power (see Power Plant Complex, above).

BANKS LAKE AND FEEDER CANAL

Banks Lake, a 27-mile long equalizing reservoir, was created by building two rock-faced earthfill dams at the north and south ends of the Ice-Age channel of the Columbia River: the Grand Coulee. Major features forming and serving Banks Lake are the 1.6 mile feeder canal with a capacity of 16,000 cubic feet per second, North Dam, 2 miles west of Grand Coulee Dam, and Dry Falls Dam and Main Canal headworks near Coulee City, 29 miles south of Grand Coulee Dam. The feeder canal was reconstructed in the late 1970s, in association with the installation of reverse action pump/generators at the pumping station: the base width was increased from 50 to 80 feed and water depth reduced from 25 to 20 feet to accommodate wave action when the waterflow is reversed. The North Dam is 145' high and contains 1,473,000 cubic yards of rock and earth. The south dam (Dry Falls Dam) is 123' high and contains 1,658,000 cubic yards of rock and earth. The Dry Falls Dam headworks contain six 12'x18' radial gates.

MAIN CANAL

The 21-mile Main Canal begins at the headworks at Dry Falls Dam and ends at Billy Clapp Lake. It consists of unlined and concrete-lined sections. Two siphons, 1,038' and 1,041' long, and two parallel tunnels, 10,037' and 9,950' long, carry water to Billy Clapp Lake (maximum capacity of 19,300 cfs). This lake, approximately 6 miles long and formed by earthfill Pinto Dam, is a segment of the canal system. Below Pinto Dam, bifurcation works divide Grand Coulee Dam irrigation water between the West Canal and East Low Canal.

WEST CANAL

The 88-mile West Canal is one of two canals formed by the bifurcation of the Main Canal. It skirts the northwest edge of the project and is carried across the lower Grand Coulee through a large inverted siphon at the north end of Soap Lake. From Soap Lake, the canal continues around the upper margin of Quincy Basin to the northern base of Frenchman Hills where it passes through a 9,000' tunnel to the Royal Slope.

EAST LOW CANAL

The 82.4 mile East Low Canal also begins at the bifurcation of the Main Canal. It extends south in a contour course through the eastern uplands to a point just east of Moses Lake. As late as 1994, the Bureau of Reclamation anticipated extension of the canal to a point 8 miles northeast of Pasco.

O'SULLIVAN DAM AND POTHOLES RESERVOIR

O'Sullivan Dam, a large zoned earthfill dam, is located on Crab Creek 15 miles south of Moses Lake, Washington. The 27,800-acre/332,200 acre feet Potholes Reservoir collects return flow from irrigation in the upper portion of the project for reuse in the southern portion. A system of waterways on both the West and East Low canals provides a means of delivering water into Potholes Reservoir to supplement the natural and return flows.

POTHOLES CANAL

The Potholes Canal begins at the headworks of O'Sullivan Dam and extends 70 miles to the southwestern and south-central portions of the project. (Irrigation Blocks 2 and 3, comprising approximately 5,000 acres at the southernmost end of the South District, receive irrigation water pumped directly from the Snake (Block 2) and Columbia (Block 3) rivers.

ADDENDUM TO:
COLUMBIA BASIN PROJECT, GRAND COULEE DAM & FRANKLIN D. ROOSEVELT LAKE
Across Columbia River, Southeast of Town of Grand Coulee
Grand Coulee
Grant County
Washington

HAER WA-139-A
HAER WASH,13-GRACO,1A-

FIELD RECORDS

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
U.S. Department of the Interior
1849 C Street NW
Washington, DC 20240-0001